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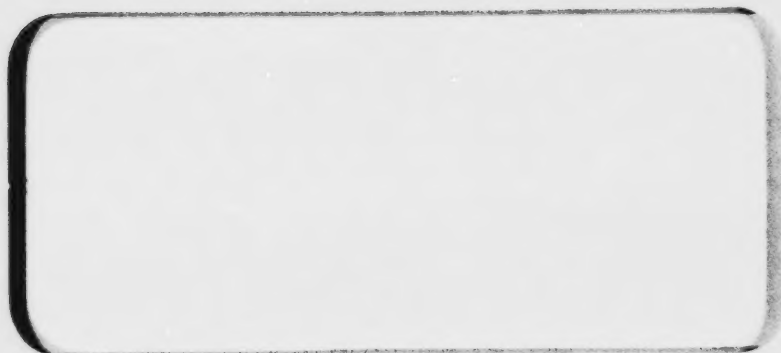


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ENVIRONMENTAL PROTECTION SERVICE
AQUATIC PROGRAM AND CONTAMINANTS CONTROL
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THE TROPHIC STATUS OF SHUSWAP LAKE

Regional Program Report 84-20

By

M. Ross

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ABSTRACT

Increasing land development in the Shuswap Lake watershed, particularly around the municipality of Salmon Arm, has created concern regarding the state of eutrophication in Shuswap Lake. In 1978 and 1979 a two-year program was conducted to document the state of eutrophication of the Salmon Arm section of Shuswap Lake. The studies included physical, chemical and biological monitoring in three main zones of the lake: Zone A - Tappen Bay area; Zone B - the main section of the Salmon Arm; Zone C - one transect in Seymour Arm.

Another study was conducted concurrently in the summer of 1978 to identify the phosphorus sources and loadings around the Salmon Arm section of Shuswap Lake where land development was greatest. The Salmon River and the District of Salmon Arm sewage treatment plant appeared to be the major sources of total phosphorus loading. Both sources discharged into lake study Zone A. The area around Zone B was less developed than the watershed around Zone A and no major sources of phosphorus inputs were identified. Zone C was located in a relatively undeveloped area.

Chemical and biological data indicated that: Zone A was mesotrophic; Zone B was oligo-mesotrophic; and Zone C was oligotrophic. The Salmon Arm sewage treatment plant could be enhancing eutrophication in Zone A.

RÉSUMÉ

Le développement croissant des terres dans le bassin versant du lac Shuswap, particulièrement près de la municipalité de Salmon Arm, a créé des inquiétudes regardant l'état d'eutrophisation du lac Shuswap. En 1978 et 1979, un programme de deux ans fut conduit pour documenter l'état d'eutrophisation de la section de Salmon Arm du lac Shuswap. Les études ont compris un contrôle physique, chimique et biologique de trois principales zones du lac: Zone A - région de la baie Tappen; Zone B - la principale section de Salmon Arm; Zone C - une section transversale de Seymour Arm.

En été 1978, une autre étude a été conduite simultanément afin d'identifier les sources et les charges de phosphore aux environs de la section de Salmon Arm du lac Shuswap où le développement des terres fut le plus intense. La rivière Salmon et l'usine de traitement des eaux usées du district de Salmon Arm semblèrent être les majeures sources de la charge en phosphore total. Ces deux sources déversaient dans la Zone A de l'étude du lac. La région autour de la Zone B était moins développée que le bassin versant autour de la Zone A et aucune source majeure d'inputs de phosphore ne fut identifiée. La Zone C était située dans une région relativement non-développée.

Les données chimiques et biologiques démontrent que: la Zone A était mésotrophe; la Zone B oligo-mésotrophe; et la Zone C oligotrophe. L'usine de traitement des eaux usées de Salmon Arm pourrait contribuer à l'accroissement de l'eutrophisation de la Zone A.

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1. INTRODUCTION

Shuswap Lake, a large lake situated in the south-central region of B.C., supports a recreational fishery and provides an important rearing area for several species of commercial salmon (Figure 1). Concerns relating to the water quality and the welfare of the fishery resource have been increasing over the past decade along with increasing land development in the lake's watershed.

The Shuswap Lake system supports annual runs of approximately 5,100 coho (Oncorhynchus kisutch), 13,100 chinook (O. tshawytscha) and 342,000 sockeye salmon (O. nerka), according to ten year average escapement data from 1968 to 1977 (Graham and Russell, 1979) (Appendix I). In addition, there are resident populations of rainbow trout (Salmo gairdneri), mountain whitefish (Prosopium williamsoni), Dolly Varden char (Salvelinus malma) and kokanee (O. nerka).

Large numbers of juvenile fish appear to migrate and rear in littoral areas in the vicinity of Mara Lake - Sicamous Narrows, southern portions of Salmon Arm, the southerly regions of Anstey Arm, the northern tip of Seymour Arm and the outlet of Shuswap Lake. The Shuswap, Eagle, Salmon, Anesty, Seymour and Adams River are all used for spawning areas (Russell et al., 1981).

Fairly good escapements were observed in the Salmon River in the fall of 1978 (350 chinook, 1500 coho and 434 sockeye) (Brown, Musgrave and Marshal, 1979). However, extensive shallows characterized by high temperatures and turbidity in the vicinity of Salmon Arm probably limit the use of this area by rearing fish. Apparently, juvenile salmon utilize the Salmon Arm foreshore areas only briefly in April and early May before migrating to other basins in the Shuswap Lake system (Russell et al., 1981). Sockeye salmon beach spawn in dominant years along the north shore of the Salmon Arm, the east shore of Anesty Arm and throughout the Main Arm. There is little beach spawning in Seymour Arm (Stewart, DFO, pers. comm., 1984).

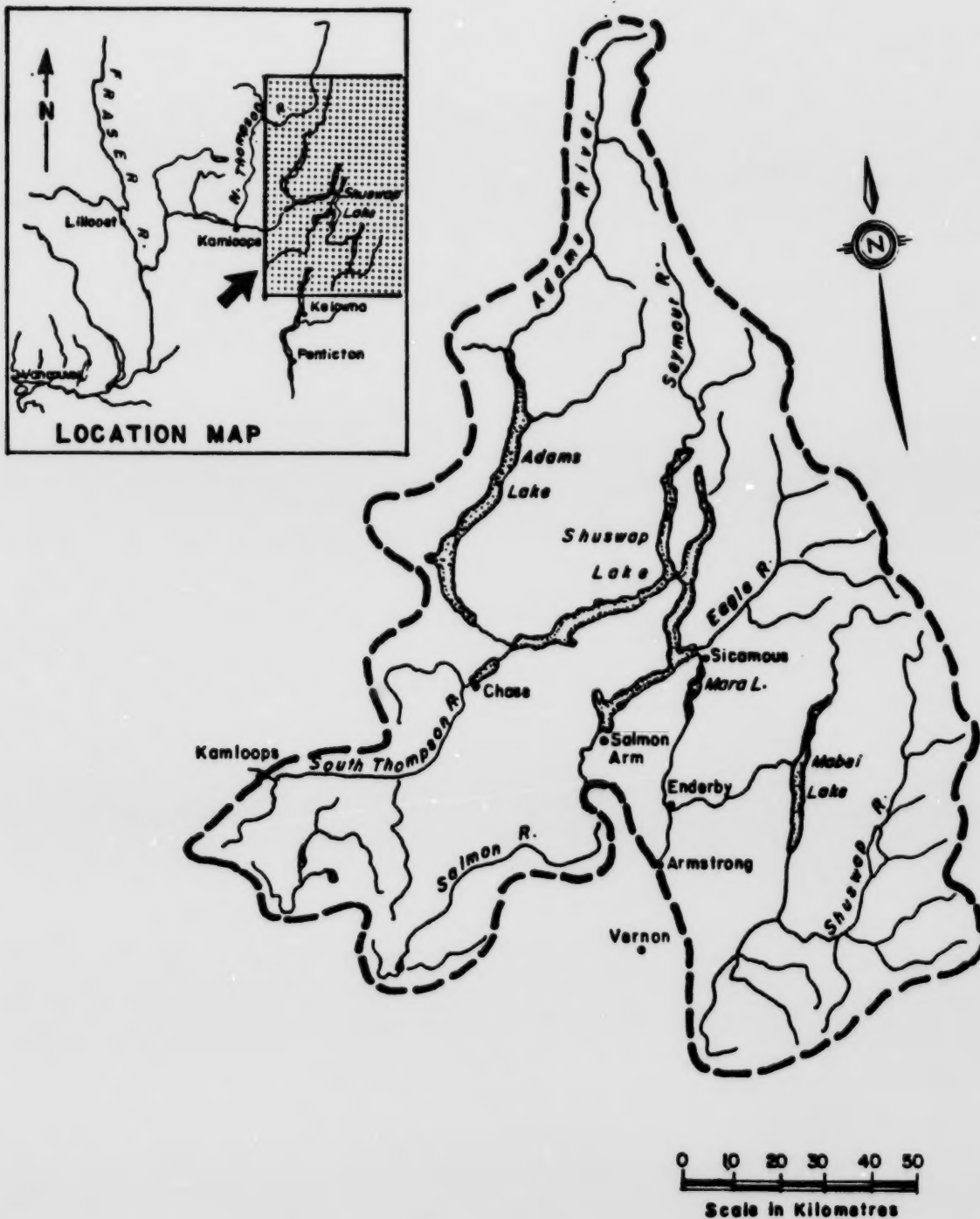


FIGURE 1 SHUSWAP LAKE WATERSHED

Very little work has been done on the water quality or limnology of Shuswap Lake. Ward (1957), reported on zooplankton populations in the lake. A small study, conducted by the B.C. Pollution Control Branch (now B.C. Waste Management Branch) in 1971 and 1972, indicated that Shuswap Lake was oligotrophic except perhaps in the Tappen Bay area of the Salmon Arm section of the lake.

The Salmon Arm section of the lake receives nutrient inputs from agricultural drainage, land development, and municipal wastes. At the time this study was initiated, the town of Salmon Arm was anticipating major improvements in its waste treatment plant. The study was therefore designed to better document the present state of eutrophication in that part of the lake, and to identify the phosphorus sources and loadings in the Salmon Arm area of the Shuswap Lake watershed.

2. STUDY AREA

2.1 Watershed

The Shuswap Lake watershed drains approximately 15,570 km² (Figure 1). The Adams, Eagle, and Shuswap Rivers flow from the Monashee Mountain Range, and eventually empty into Shuswap Lake. The Salmon River flows directly into Shuswap Lake from a sub-basin to the south. Shuswap Lake itself is the headwater for the South Thompson River watershed which drains the south central region of British Columbia.

Some drainage basin characteristics are listed in Table 1.

TABLE 1 DRAINAGE BASIN CHARACTERISTICS

PARAMETER	Characteristics
Location of Lake	- most northern point (Seymour Arm) 51°13'45" - most southern point (Tappen Bay - town of Salmon Arm) 30°41'30" - most eastern point (east shore of Anstey Arm) 118°53'15" - most western point (outlet to South Thompson River) 119°33'30"
Mean Elevation of Lake	- 347 meters
Climate	- semi-arid continental
Area of Drainage Basin	- 15,570 km²
Limnological Region	- 6 - Columbia Mountains (Northcote and Larkin, 1963)
Basin	- open basin

2.2 Geology

The rock formations of the area surrounding Shuswap Lake are primarily Pre-Cambrian in origin (Daly, 1915). Granitic masses characteristic of the area at the extremity of Salmon Arm are geologically more recent and are believed to be of Jurassic origin. There is a large formation of limestone on the northwest shores of Salmon Arm. A few smaller formations are present at other weakly separated localities. Granite formations make up most of the area surrounding Seymour and Anstey Arms. Most of the district surrounding the Main Arm is composed of greenstones which Daly (1915) suggests are basaltic (Ward, 1957).

2.3 Morphometry

Shuswap Lake's large surface area (Table 2) is characteristic of lake basins formed by river activity. The high shoreline development ratio of 5 is also characteristic of the dendritic outlines of rivers occupying flooded river valleys that then become lakes.

A high shoreline development ratio may reflect great potential for development of littoral communities. However littoral development, part of the eutrophication process, is dependent not only on shoreline development but on depth and shoreline slope as well. For example, Zone A is the shallowest section of the lake and shoreline slope is low (Figure 2); both characteristics favour littoral development. There is not as much potential for littoral development in Zone B or C because these areas are deeper and the shoreline slope is much greater than in Zone A.

Relative depth is measured as the ratio of maximum depth to the surface area of the lake. In the case of Shuswap Lake the small relative depth indicates that the lake has a relatively large surface area to maximum depth.

The mean to maximum depth ratio indicates the approach of a lake basin to that of a cone. Like most lakes, the value for Shuswap Lake is between 0.33 and 0.5, the value for a conical depression.

Volume development is a similar index to the mean to maximum depth ratio and is defined as an index of comparison of the shape of the basin to an inverted cone with a height equal to maximum depth and a base equal to the lake's surface area. The average value found for most lakes is 1.27 and 1.40 (Cole, 1975). Shuswap Lake has a slightly lower volume development with an index of 1.15.

TABLE 2 MORPHOMETRIC FEATURES OF SHUSWAP LAKE

PARAMETER	DIMENSIONS
Lake Surface Area	310 km ²
Shoreline Length	312 km
Shoreline Development Ratio ¹	5
Maximum Depth	162 m
Mean Depth	62 m
Relative Depth ²	0.82 %
Volume	1.91 x 10 ¹⁰ m ³
Mean Depth/Maximum Depth ³	0.38
Volume Development	1.15

¹Shoreline Development Ratio = ratio of the length of the shoreline to the length of a circumference of a circle of equal area.

²Relative Depth = $88.6 \text{ (Maximum Depth) / (Surface Area)}$.

³Mean Depth/Maximum Depth = mean depth divided by the maximum depth.

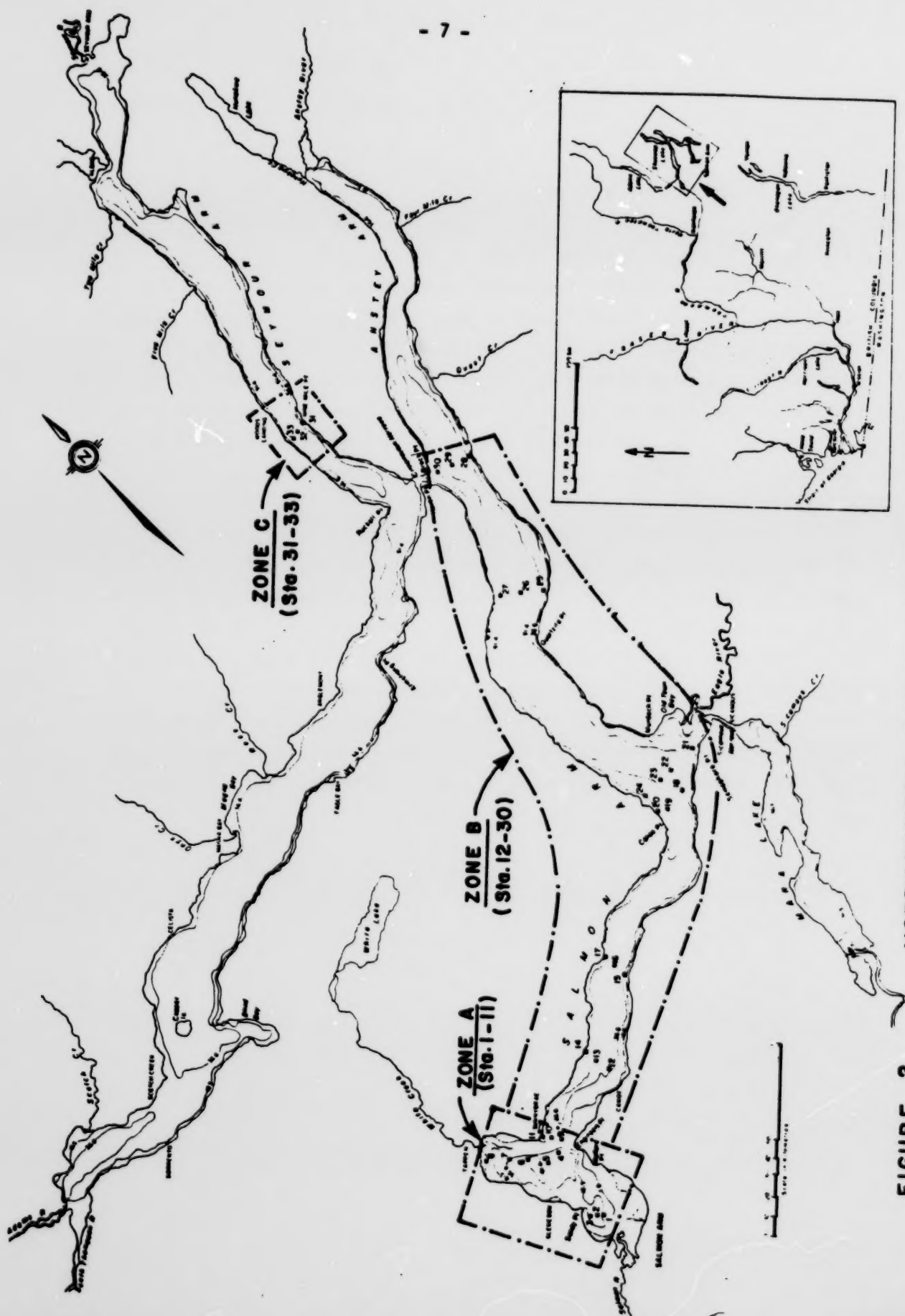


FIGURE 2

MORPHOMETRIC MAP OF SHUSWAP LAKE

3. MATERIAL AND METHODS

3.1 Phosphorus Loadings

Possible sources of phosphorus loadings into the Salmon Arm of Shuswap Lake were identified from land use maps and site investigations in May 1978 (Table 3, Figure 3). On August 15, 16 and 17, 1978, flow measurements were recorded with a Mead Velocity Probe, and single grab samples for total phosphorus were collected at the sample stations shown in Table 4 and Figure 4. The total phosphorus samples were sent to the Environmental Protection Service/Fisheries and Oceans laboratory for analysis.

On December 30, 1981 in a memo to File, R.T. Little (Waste Management Branch, [WMB], Kamloops) reported on the comparative nutrient impact on Shuswap Lake from the Salmon Arm sewage treatment plant and the Salmon River. R. Little used nutrient concentrations from the sewage treatment plant effluent and a flow of 1818 m³/day to determine a mean daily nutrient load from the sewage treatment plant. To determine Salmon River nutrient loadings both on an average daily basis and a total annual basis, Little used file data for nutrient concentrations at the mouth of the Salmon River and historical mean flows from freshet and non-freshet periods.

TABLE 3 POTENTIAL SOURCES OF NUTRIENTS IN THE SALMON ARM AREA IN 1978*

-
1. Area of grazing leases (issued by Columbia-Shuswap Regional District).
 2. Tappin Sanitary Landfill (31 to 38 m³/day).
 3. Sandy Point Resort (septic tank - 45,460 litres/day of domestic wastewater to ground).
 4. Area of grazing in Eden fire area (issued by B.C. Forestry).
 5. Bernare and Linda Petty-Abattoir (Grease removal and septic tank - 1360 litres/day of abattoir effluent to ground).
 6. a) Salmon Arm Water Pollution Control Centre (secondary activated sludge - 2.7 x 10⁶ litres/day - to open ditch to Salmon Arm).
b) Noca Dairy (Shuswap Okanagan Dairy Ind., Co-op Assoc.) Creamery (Four 4546-litre holding tanks - emptied once per day - Whey to open ditch to Salmon Arm).
c) Salmon Arm Meat and Produce - Abattoir (floor washing to storm drain to open ditch to Salmon Arm).
 7. Reliance Septic Tank - septic tank pumpage (exfiltration basin - 2730 litres/day - to ground).
 8. Salmon Arm Landfill (101 m/day).
 9. Deep Creek Landfill (18 m/day).
 10. Federated Co-op - sawmill (54370 liters of cooling water every 2 weeks - to Salmon Arm).
 11. Silver Sands Beach Development (secondary package STP, 45460 litres/day of domestic wastewater to ground) - proposed.
 12. Sicamous Landfill.
 13. C.D. Dewar - Septic tank pumpage (exfiltration and evaporation lagoon - 400 IGPD).
-

*Refer to Figure 3

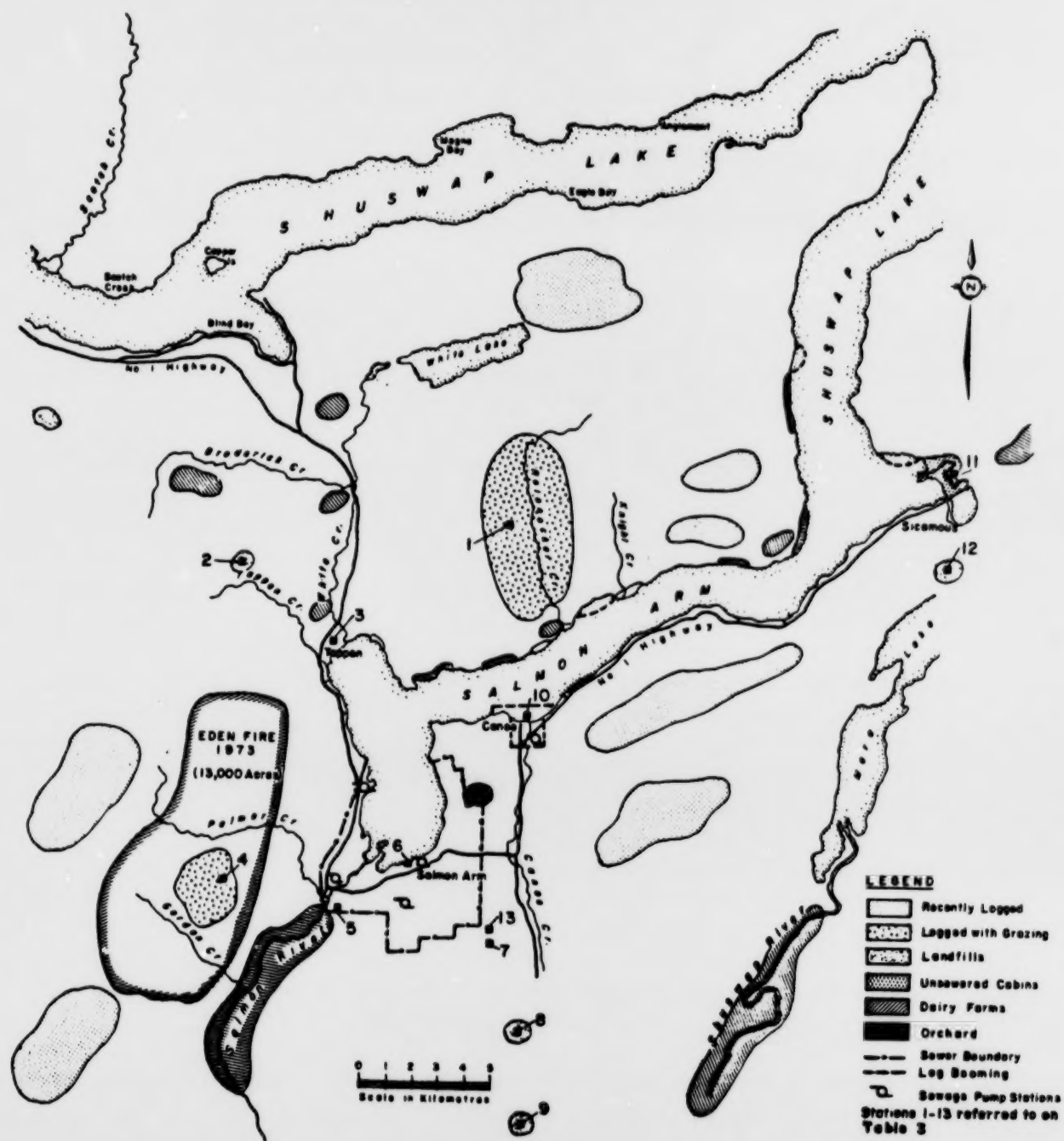


FIGURE 3 POTENTIAL SOURCES OF NUTRIENTS IN THE SALMON ARM AREA

TABLE 4 SAMPLE STATON LOCATIONS FOR PHOSPHORUS LOADING STUDY*
- August 15 to 17, 1978

STATION	NUMBER*
Reinecker Ck.	S1
White Ck.	S2
Tappen Ck.	S3
Salmon River	S4
Palmer Ck.	S5
Gordon Ck.	S6
Sewage Treatment Plant Stormdrain	S7
Stormdrain	S8
Stormdrain	S9
Canoe Creek	S10
Shuswap River	S11
Eagle River	S12
Salmon Arm Sewage Treatment Plant Discharge	STP

*Refer to Figure 4

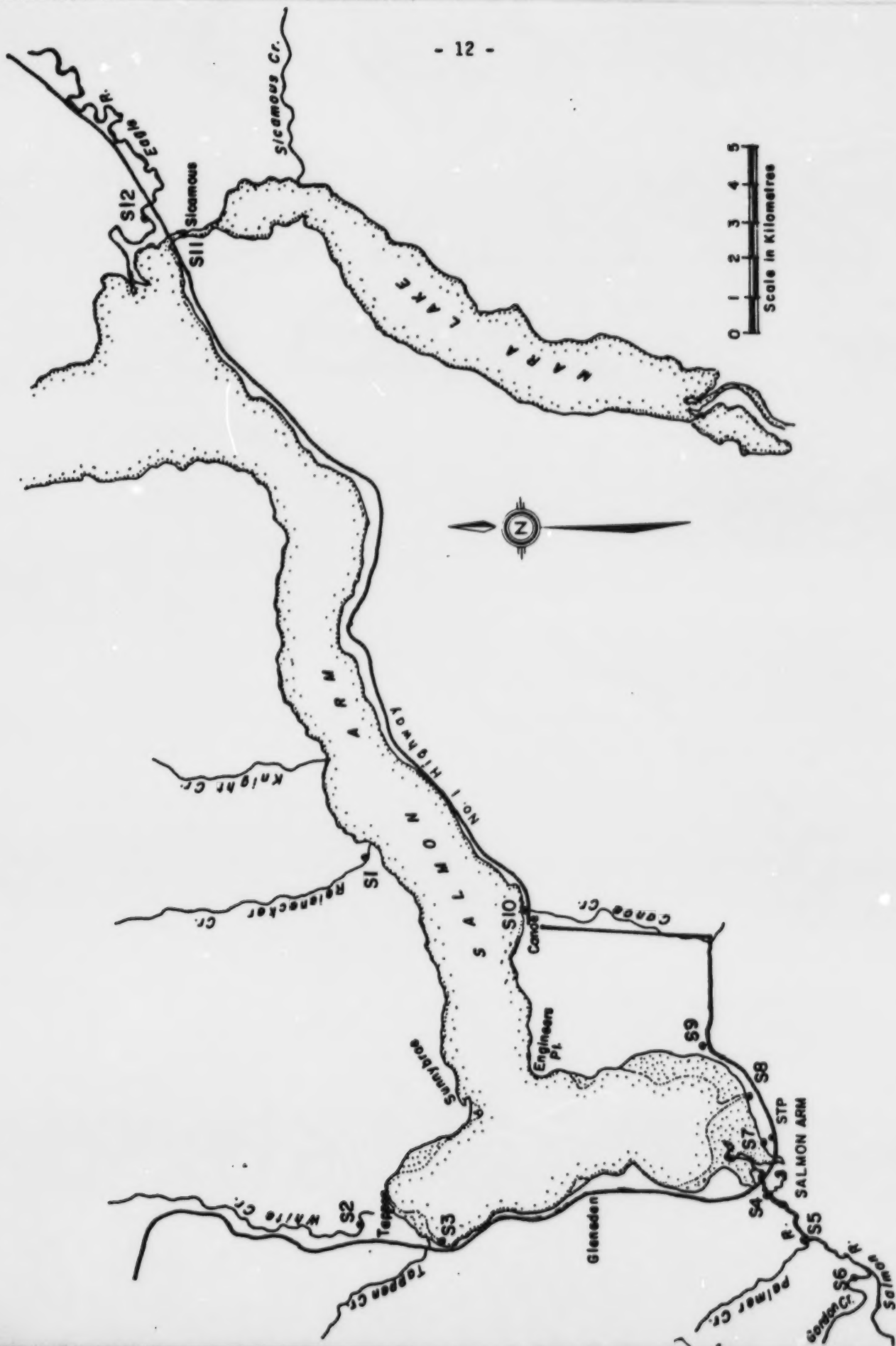


FIGURE 4 SAMPLE STATION LOCATIONS FOR PHOSPHORUS LOADING STUDY - August 15-17, 1978

3.2 Lake Study

The study area was separated into three main zones (Figure 5) in order to condense the large amount of data collected. Zone A (Tappen Bay Area) included stations 1 to 11 and was the area expected to show the greatest impact of nutrient loading. Zone B, the main section of Salmon Arm arm, included stations 12 to 30. Zone C was one transect (Stations 31 to 33) in Seymour Arm at Nine Mile Point and served as a control area in 1978. In 1979, a more intensive study was conducted in the Tappen Bay area with the same stations 1 to 11 used in Zone A while Station 16 in Zone B served as the control. Four shallow water stations (SA-S1 to SA-S4) were added in 1979 to monitor periphyton; Station SA-S4 served as the control (Figure 6).

3.2.1 Water Quality. Samples were collected at stations 1 through to 33 in June and September of 1978. Due to adverse weather conditions in November 1978, only Stations 1 to 11, 13 and 16 were sampled. In 1979, stations 1 to 11 and 16 were sampled in April, June, August and October.

Sample station location was determined with the aid of a Veb Freiburger Präzisionsmechanik yacht sextant (serial no. 108596) and a Model FE-502 Furuno Echo Sounder. Surface temperatures were recorded with a field thermometer and temperature profiles were recorded with a Kahl Scientific Instrument Corporation Bathythermograph.

Water samples for chemical analyses were collected with six litre Van Dorn water bottles at four depths: one meter below the surface, 1-2 meters above the thermocline, 1-2 meters below the thermocline and 1-2 meters from the bottom. The following chemical parameters were analysed:

pH	Total Phosphate Phosphorus	Nitrite/Nitrate Nitrogen
Oxygen	Total Dissolved Phosphate	Total Dissolved Nitrogen
Conductivity	Ammonia Nitrogen	Silica Dioxide
		Particulate Carbon/Nitrogen

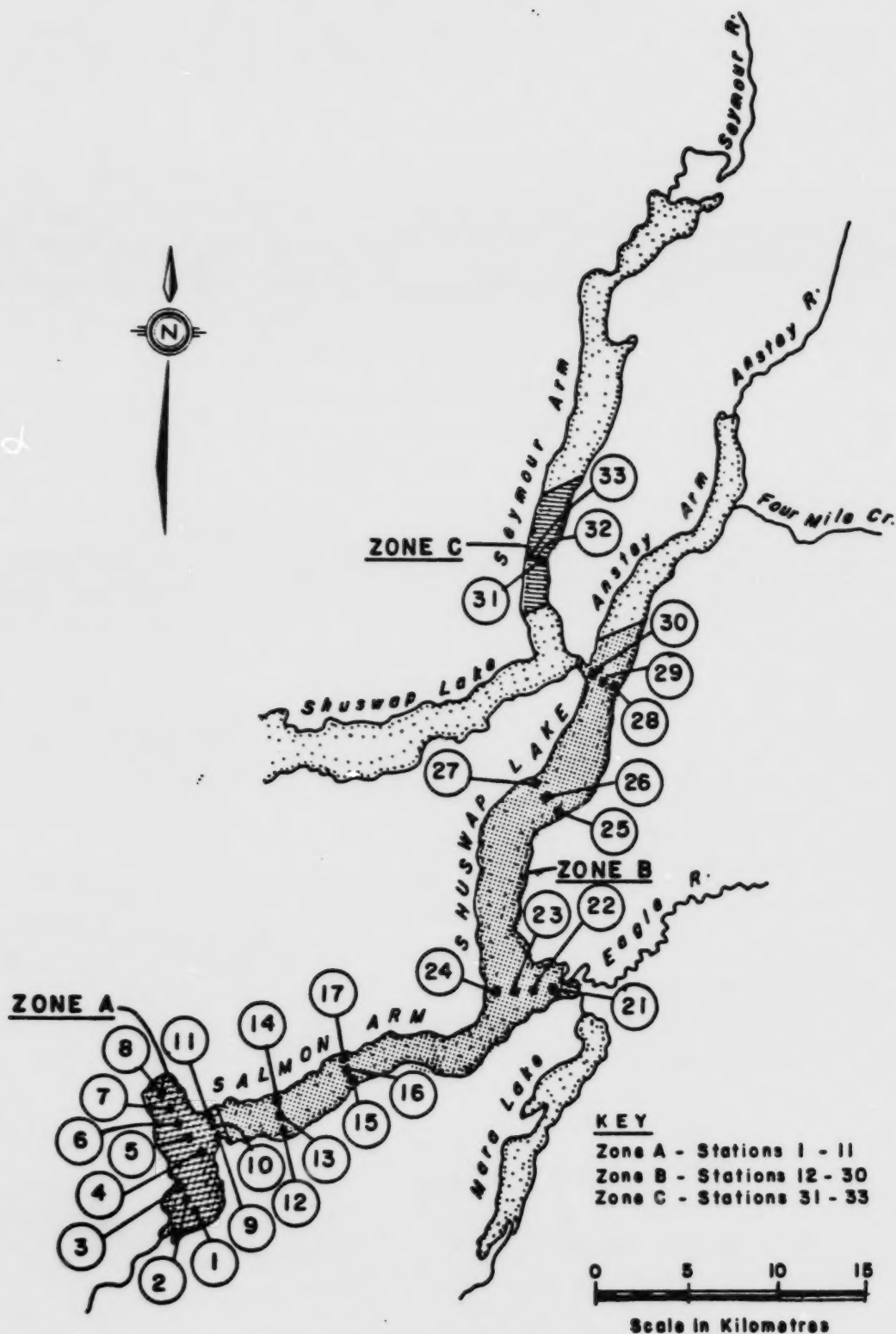


FIGURE 5 LAKE SURVEY-STUDY ZONES AND SAMPLE STATION LOCATIONS

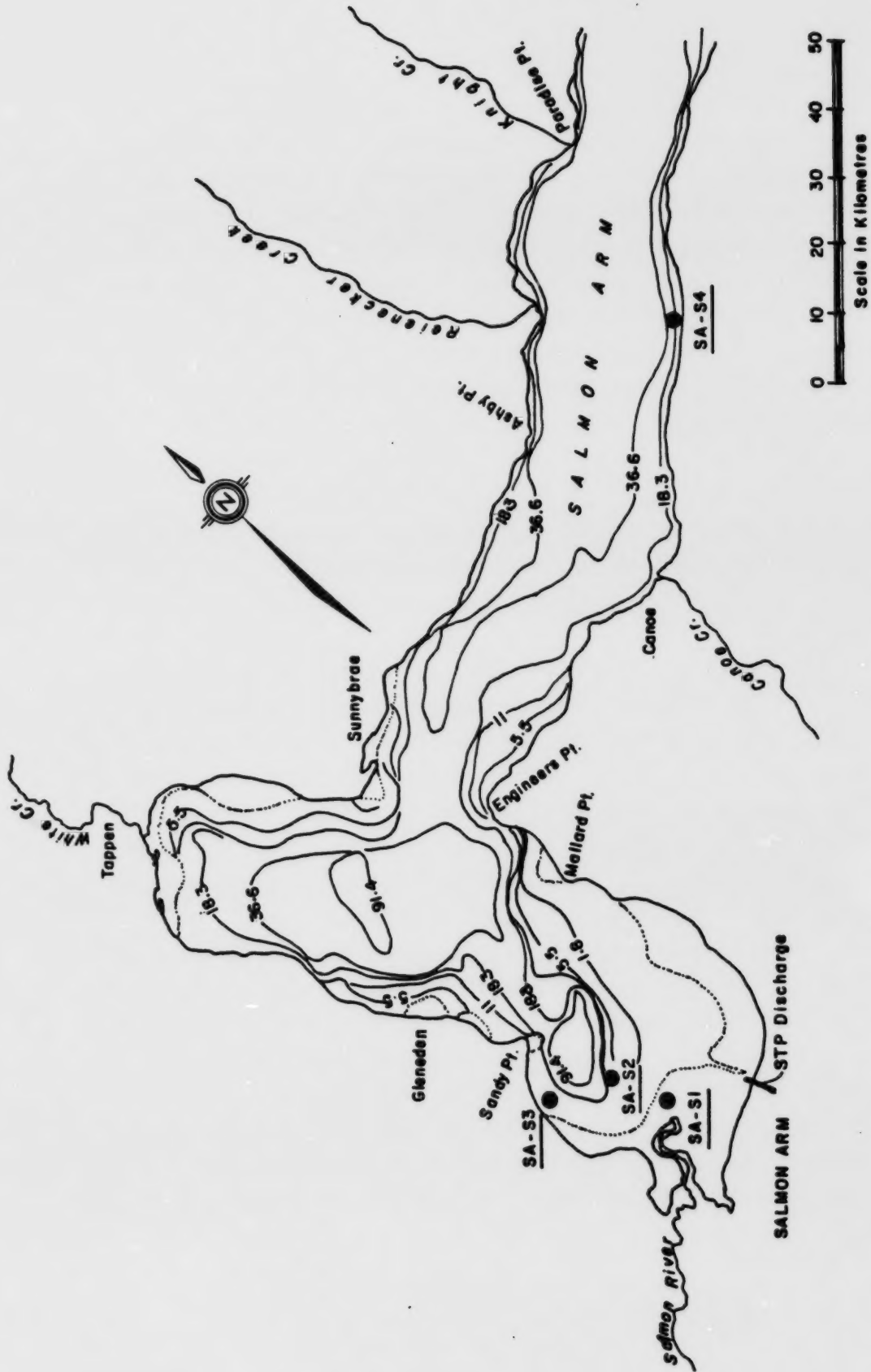


FIGURE 6 SHALLOW WATER STATIONS

The total dissolved phosphate sample was filtered immediately through a distilled water washed 0.45 micron Sartorius membrane filter.

At the end of each day, particulate carbon and nitrogen samples were filtered through roasted GF-C Whatman glass filters. Dissolved oxygen was determined according to the modified Winkler titration method. Samples were then packed in wet ice and shipped to the Inland Waters Directorate Water Quality Laboratory in West Vancouver in 1978 and to the Environmental Protection Service/Fisheries and Oceans Laboratory in 1979. The Inland Waters Laboratory analyzed the particulate carbon/nitrogen and total dissolved nitrogen samples in 1978 and 1979. Samples collected on a weekend were kept cool and shipped to the respective laboratories the following Monday.

The one meter water samples collected at the four shallow water stations in 1979 were analysed for the chemical parameters listed above with the exception of dissolved oxygen.

3.2.2 Periphyton. The shallow water periphyton samplers were first installed at stations SA-S2 to SA-S4 on April 23, 1979 and at station SA-S1 on May 29, 1979. The stations were subsequently sampled at three week intervals until October 23, 1979. The artificial substrate samplers at each station consisted of two plates of roughened plexiglass of 170 cm² surface area. The plates were attached to a float of wood and styrofoam suspended 1.5 meters below the surface and anchored to the bottom with a cable and concrete building block (Truscott and Kelso, 1979).

Periphyton plates were retrieved every three weeks and new plates were installed. The attached material was scraped off the plexiglass with the aid of a glass slide into a container of distilled water and then split into three aliquots using a Folsom plankton splitter. One-half of the sample was sent to the laboratory for ash-free dry weight analysis; one-quarter was filtered through a Whatman GF/C glass-fiber filter and shipped frozen to the laboratory for chlorophyll-a and pheopigment analysis; and one-quarter was preserved in Lugol's solution and sent to the

laboratory for algal identification and enumeration as described by Ennis (Truscott & Kelso, 1979).

3.2.3 Phytoplankton. Starting in September 1978, an attempt was made to determine in situ chlorophyll-a profiles at stations 1 to 33 using a Turner Design Model 10-005R Field Fluorometer. An estimate of the photic zone was determined by multiplying the Secchi disk reading by 2.5 (Vollenweider, 1971). Fluorometer readings were taken from the surface to the bottom of the estimated photic zone by lowering a submersible pump and pumping water from 1 meter depth intervals. To correlate the fluorometer readings with a chlorophyll-a value, additional 1 or 2 litre grab samples were drawn off at 5 or 6 depths at every third or fourth station. These samples were filtered through a Whatman GF/C glass fiber filter and transported frozen to the laboratory for chlorophyll-a analysis. Unfortunately, the correlation between the fluorometer and laboratory analysis was less than .5; thus the actual values for the chlorophyll-a profiles could not be calculated.

Phytoplankton samples were collected at 4 depths within the photic zone over the range where the highest fluoremetric readings had been recorded. The samples were then preserved with Lugol's solution. Numerical identification and biovolumes were then determined at the EPS biology laboratory in North Vancouver as described by Ennis (Truscott & Kelso, 1979).

4. RESULTS AND DISCUSSION

4.1 Phosphorus Loading

The total phosphorus concentration from the Salmon Arm sewage treatment plant (STP) was an order of magnitude higher than concentrations from a stormdrain in the municipality of Salmon Arm and about two orders of magnitude greater than most stream inputs (Table 5).

Total phosphorus loadings were greatest from Shuswap River, Salmon River, Salmon Arm sewage treatment plant and the Eagle River, (Table 5). Both the Shuswap River and the Eagle River empty into Zone B. The significant sources of total phosphorus loading to Zone A were the Salmon River and the Salmon Arm sewage treatment plant. In August 1978, total phosphorus loadings from these two sources were approximately equal, and at least five times greater than any other loadings to Zone A.

In a memo to file dated December 30, 1981, R. Little (WMB, Kamloops) reported on the comparative nutrient impact to Shuswap Lake from the Salmon Arm STP and the Salmon River. A mean daily nutrient load from the STP was determined using mean effluent nutrient concentrations and mean daily recorded flows. Average daily and total annual nutrient loadings from the Salmon River were calculated using WMB nutrient concentration data for Salmon River and Water Survey of Canada (WSC) historical mean flows for freshet and non-freshet periods (Table 6).

The percentage of phosphorus loading, by the STP as compared to the Salmon River was calculated from R. Little's data. During freshet periods the STP only contributed about 3% of the total phosphorus loading and 12% of the total dissolved phosphorus loading to Zone A. During intermediate flow periods the STP contributed about 21% of the total phosphorus loading and 23% of the dissolved phosphorus loading. More importantly, during low flow periods i.e. early spring and late summer, the STP made a much more significant contribution to phosphorus loading: 40% of total phosphorus loading and 41% of dissolved phosphorus loading.

TABLE 5 CONCENTRATIONS AND LOADINGS OF TOTAL PHOSPHORUS SOURCES TO SHUSWAP
LAKE - AUGUST 15 TO 17, 1978

<u>STATION (see Figure 4)</u>		<u>CONCENTRATION OF SINGLE SAMPLE (mg/l)</u>
STP	Salmon Arm STP	5.82
S8	Stormdrain	0.562
S2	White Creek	0.090
S4	Salmon River	0.069
S5	Palmer Creek	0.068
S10	Canoe Creek	0.0604
S3	Tappen Creek	0.040
S9	Stormdrain	0.021
S12	Eagle River	0.0152
S11	Shuswap River	0.012
S6	Gordon Creek	0.0050
S1	Reinecker Creek	< 0.0050

<u>STATION</u>	<u>LOADING (kg/day)</u>
S11 Shuswap River	71.64
S4 Salmon River	10.43
STP Salmon Arm STP	10.22
S12 Eagle River	4.68
S2 White Creek	1.93
S3 Tappen Creek	1.40
S10 Canoe Creek	0.86
S5 Palmer Creek	0.61
S8 Stormdrain	0.17
S1 Reinecker Creek	0.08
S6 Gordon Creek	0.03
S9 Stormdrain	0.004

TABLE 6 COMPARATIVE NUTRIENT IMPACT ON SHUSWAP LAKE FROM THE SALMON ARM STP AND THE SALMON RIVER

- Memo to File December 30, 1981, By R.T. Little (W.M.B., Kamloops)

1. Salmon Arm STP - average daily flow 1818 m³/day (400,000 GPD).

(a) Total Phosphorus

mean concentration = 5.17 mg/l

(R = 3.56 - 8.89; S.D. = 1.63 n = 10)*

$$\text{load} = 5.17 \frac{\text{gm}}{\text{m}^3} \times 1818 \frac{\text{m}^3}{\text{day}} = 9.4 \text{ kg./d}$$

(b) Ortho Phosphorus (Dissolved)

mean concentration = 3.87 mg/l

(R = 2.87 - 4.80; S.D. = 6.2; n = 7)

$$\text{load} = 3.87 \frac{\text{gm}}{\text{m}^3} \times 1818 \frac{\text{m}^3}{\text{day}} = 7.0 \text{ kg./d}$$

(c) Total Inorganic Nitrogen as (NH₄⁺ + NO₃)

mean concentration = 19.42 mg/l

(R = 11.1 - 26.83, S.D. = 5.54; n = 9)

$$\text{load} = 19.42 \frac{\text{gm}}{\text{m}^3} \times 1818 \frac{\text{m}^3}{\text{day}} = 35.3 \text{ kg./d}$$

2. Salmon River - flows determined from monthly means from Water Survey of Canada data 1961-1979.

i. Freshet Flow (May, June) - mean flow = 15.4 m³/sec.

(a) Total Phosphorus

mean concentration = .233 mg/l

(R = .108 - .398 mg/l)

$$\text{load} = .233 \frac{\text{gm}}{\text{m}^3} \times 15.4 \frac{\text{m}^3}{\text{sec.}} \times 86400 \frac{\text{sec.}}{\text{day}} = 310 \text{ kg./d}$$

*R = range

S.D. = standard deviation

n = no. of samples

TABLE 6 COMPARATIVE NUTRIENT IMPACT ON SHUSWAP LAKE FROM THE SALMON ARM STP AND THE SALMON RIVER

(Continued)

(b) Total Dissolved Phosphorus

mean concentration = .038 mg/l

(R = .027 - .046; S.D. = .008; n = 5)

$$\text{load} = .038 \frac{\text{gm}}{\text{m}^3} \times 15.4 \frac{\text{m}^3}{\text{sec.}} \times 86400 \frac{\text{sec.}}{\text{day}} = 50.6 \text{ kg./d}$$

(c) Total Nitrogen ($\text{NH}_4^+ + \text{NO}_3$)

mean concentration = .097 mg/l

(R = .038 - .161; S.D. = .044, n = 5)

$$\text{load} = .097 \frac{\text{gm}}{\text{m}^3} \times 15.4 \frac{\text{m}^3}{\text{sec.}} \times 86400 \frac{\text{sec.}}{\text{day}} = 132.7 \text{ kg./d}$$

ii. Intermediate Flow (April, July) - and mean flow = $4.4 \text{ m}^3/\text{sec.}$

(a) Total Phosphorus

mean concentration = .092 mg/l

(R = .062 - .139; S.D. = .034; n = 4)

$$\text{load} = .092 \frac{\text{gm}}{\text{m}^3} \times 4.4 \frac{\text{m}^3}{\text{sec.}} \times 86400 \frac{\text{sec.}}{\text{day}} = 35.0 \text{ kg./d}$$

(b) Total Dissolved Phosphorus (Ortho)

mean concentration = .063 mg/l

(R = .051 - .085; S.D. = .019; n = 3)

$$\text{load} = .063 \frac{\text{gm}}{\text{m}^3} \times 4.4 \frac{\text{m}^3}{\text{sec.}} \times 86400 \frac{\text{sec.}}{\text{day}} = 24.0 \text{ kg./d}$$

(c) Total Nitrogen

mean concentration = .071 mg/l

(R = .036 - .160; S.D. = .050, n = 5)

$$\text{load} = .071 \frac{\text{gm}}{\text{m}^3} \times 4.4 \frac{\text{m}^3}{\text{sec.}} \times 86400 \frac{\text{sec.}}{\text{day}} = 27 \text{ kg./d}$$

TABLE 6 COMPARATIVE NUTRIENT IMPACT ON SHUSWAP LAKE FROM THE SALMON
ARM STP AND THE SALMON RIVER

(Continued)

iii. Non Freshet Flow (January to March, August to December) -
mean flow = $2.43 \text{ m}^3/\text{sec.}$

(a) Total Phosphorus

mean concentration = $.066 \text{ mg/l}$

(R = $.054 - .085$; S.D. = $.010$; n = 11)

$$\text{load} = .066 \frac{\text{gm}}{\text{m}^3} \times 2.43 \frac{\text{m}^3}{\text{sec.}} \times 86400 \frac{\text{sec.}}{\text{day}} = 13.9 \text{ kg./d}$$

(b) Total Dissolved Phosphorus (Ortho)

mean concentration = $.049 \text{ mg/l}$

(R = $.043 - .051$; S.D. = $.003$; n = 10)

$$\text{load} = .049 \frac{\text{gm}}{\text{m}^3} \times 2.43 \frac{\text{m}^3}{\text{sec.}} \times 86400 \frac{\text{sec.}}{\text{day}} = 10.3 \text{ kg./d}$$

(c) Total Nitrogen

i. Winter

mean concentration = $.211 \text{ mg/l}$

(R = $.072 - .237$, S.D. = $.117$, - n = 6)

$$\text{load} = .211 \frac{\text{gm}}{\text{m}^3} \times 2.43 \frac{\text{m}^3}{\text{sec.}} \times 86400 \frac{\text{sec.}}{\text{day}} = 44.3 \text{ kg./d}$$

ii. Non-winter

mean concentration = $.034 \text{ mg/l}$

(R = $.007 - .050$, S.D. $.034$, n = 6)

$$\text{load} = .034 \frac{\text{gm}}{\text{m}^3} \times 2.43 \frac{\text{m}^3}{\text{sec.}} \times 86400 \frac{\text{sec.}}{\text{day}} = 7.14 \text{ kg./d}$$

4.2 Lake Study

4.2.1 Physical Characteristics.

4.2.1.1 Temperature. Shuswap Lake is monomictic, circulating freely in the winter and stratifying in the summer. During the 1978-79 study, the lake stratified in late April/early May, and turned over sometime in early November. Typical temperature profiles are represented by Station 2 and 6 in Zone A and Station 16 in Zone B (Figure 7).

Most of the lake stations were still isothermal in the early spring (April 1979) and had stratified by early summer (June 1979); therefore stratification of Shuswap Lake probably corresponded closely with the peak flows of the Salmon River (Figure 8) which occurred in late spring, near the end of May. In early summer (June) the depth of the epilimnion was between 5 and 10 meters. By the fall (October), temperatures dropped and the epilimnion deepened to between 15 and 20 meters. By late fall, early winter (November 1978) the lake was isothermal; so fall turnover probably occurred sometime in early November.

4.2.1.2 Photic zone. The photic zone, approximately equal to 2.5 x secchi depth (Vollenweider, 1971) increased from Zone A to Zone C (Figure 9) along with a corresponding decrease in turbidity (Figure 10) and decrease in phytoplankton biomass (Section 4.2.3.1, Table 12).

Seasonal variations as well as zonal differences were noted in the photic zone. The photic zone was shallowest in the spring (June 1978 and 1979), soon after the spring freshet peak flow; and then increased through to fall (June to November 1978 and June to October 1979) in all three zones.

4.2.1.3 Turbidity. Turbidity decreased from Zone A to Zone C (Figure 10) along with the amount of suspended matter in the water. Zone A is a smaller, shallower body of water than both Zone B or C. Therefore, the

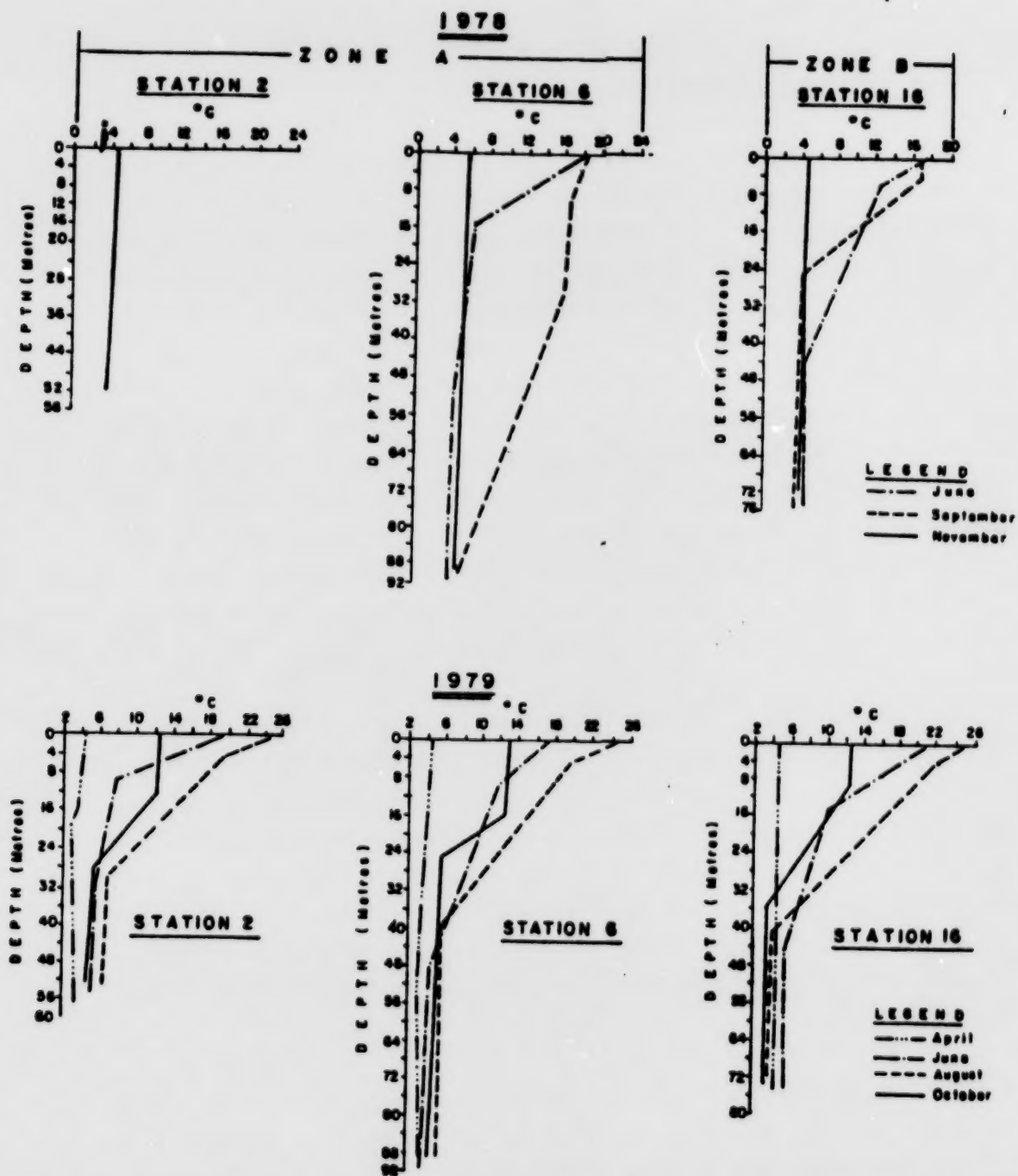


FIGURE 7 TEMPERATURE PROFILES FOR STATIONS 2,6, AND 16

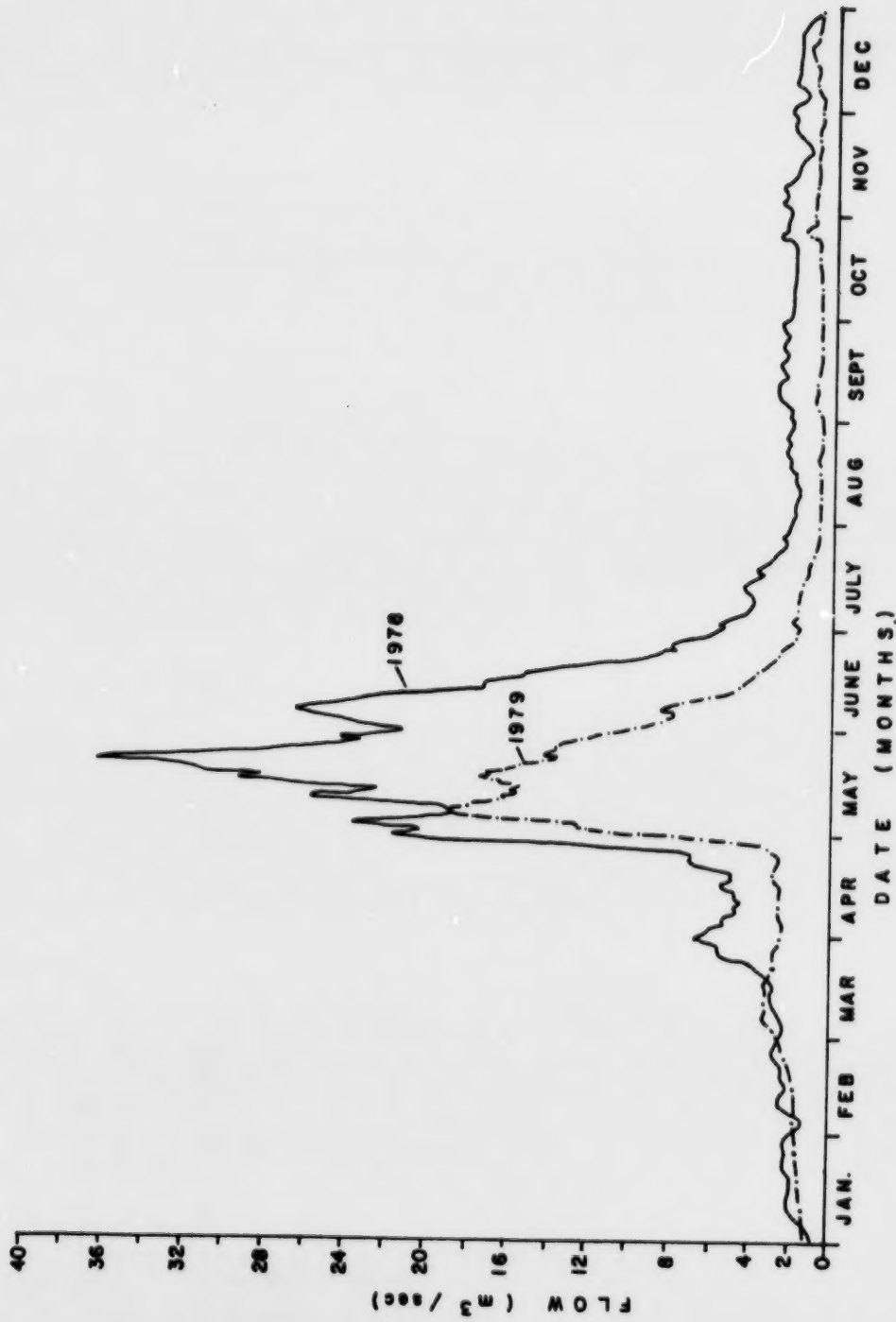


FIGURE 8 SALMON RIVER FLOW FOR 1978 AND 1979
(Water Survey of Canada, 1978 and 1979)

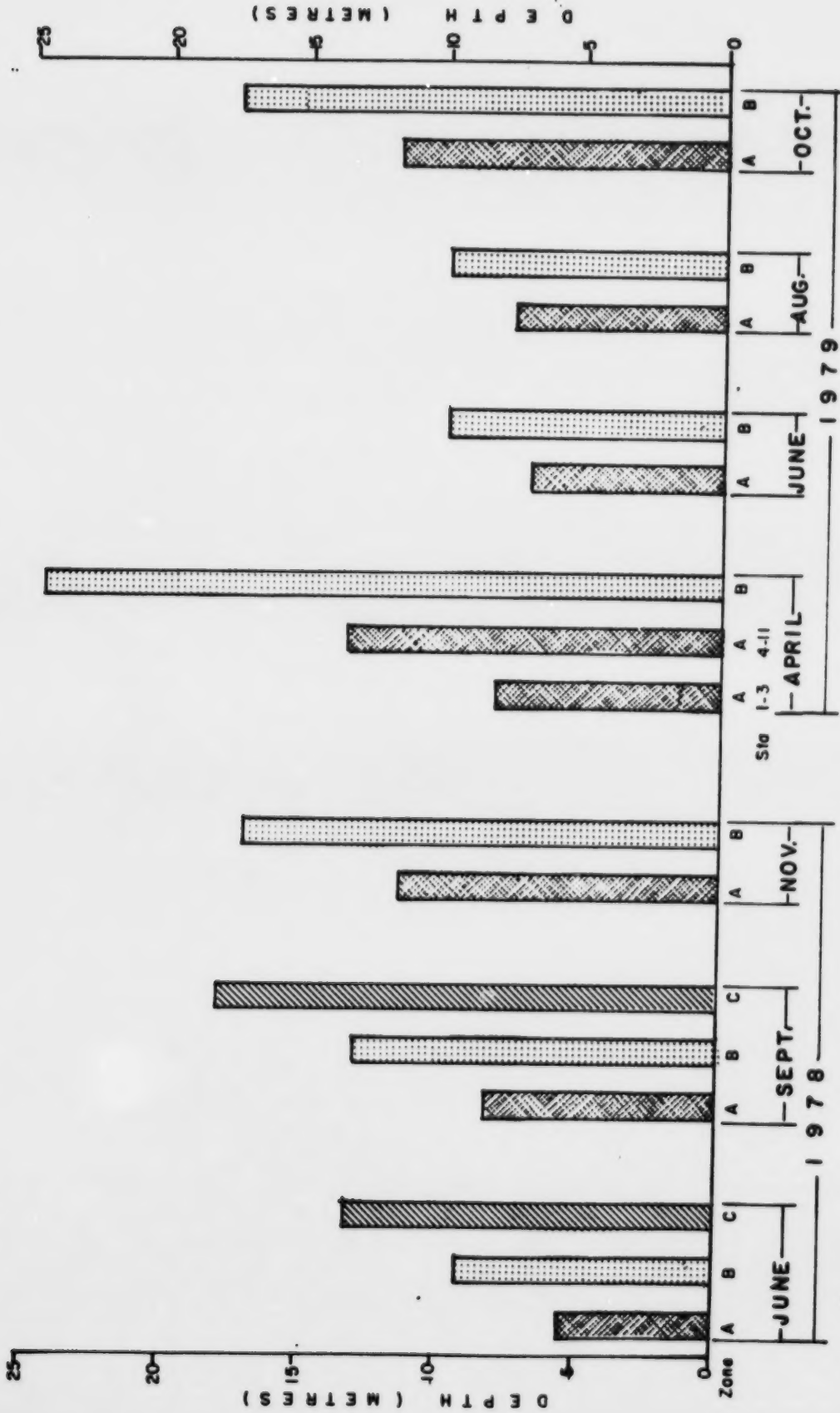


FIGURE 9 PHOTIC ZONE IN SHUSWAP LAKE DURING 1978 AND 1979

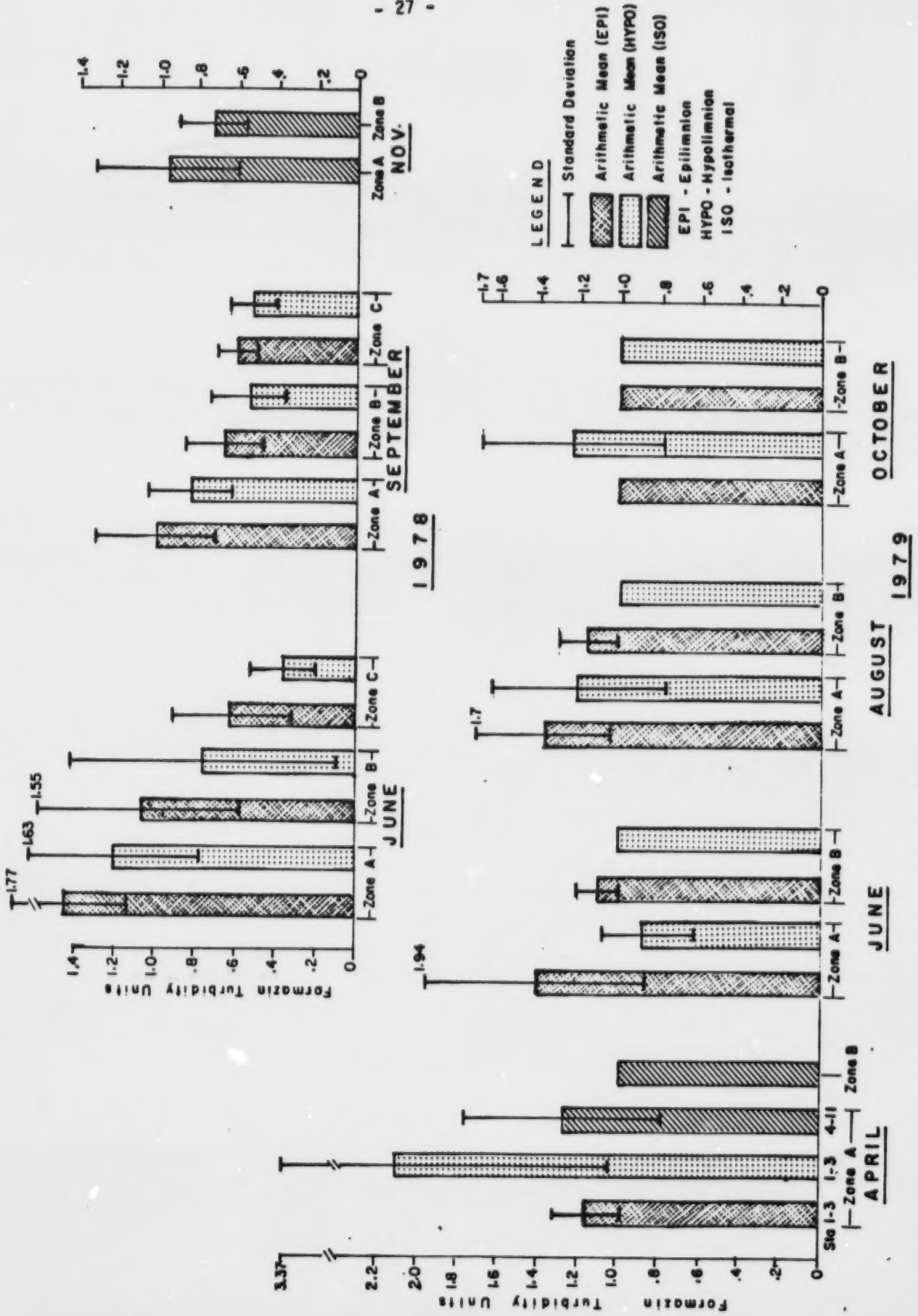


FIGURE 10 TURBIDITY READINGS IN SHUSWAP LAKE DURING 1978 AND 1979

sediment load from runoff and from anthropogenic sources, compared to the volume of the receiving water is possibly greater in Zone A than in Zone B or C. Phytoplankton biovolume was also more abundant in Zone A at the time of sampling (Section 4.2.3.1, Table 12) which would have increased turbidity.

Seasonal variation, as well as zonal variation was evident. Turbidity was highest in all three zones during the spring and summer and decreased in the fall. In the spring, turbidity was probably caused by abiotic sources, i.e. an increase in sediment loading and disturbance of settled particulate matter by spring runoff. For example, in April 1979, approximately a week before peak freshet flow, when Stations 1-3 were stratified, turbidity was higher in the hypolimnion than the epilimnion. Sediment, or abiotic particles, may have settled out and become trapped below the thermocline, increasing turbidity in the hypolimnion. By summer, river flows decreased, phytoplankton populations increased and turbidity was greater in the epilimnion than the hypolimnion. In Zone A, in October 1979, after phytoplankton populations declined sharply, sinking algae and abiotic suspended particles increased turbidity in the hypolimnion making it greater than epilimnetic turbidity.

4.2.2 Chemical Characteristics.

4.2.2.1 pH. By definition, pH values cannot be averaged arithmetically, but must be estimated by the logarithm of the reciprocals (Wetzel, 1975). the following equation was used to calculate mean pH;

$$\text{Log } 10 \quad \frac{1}{\frac{1}{10^{\text{pH}_1}} + \frac{1}{10^{\text{pH}_2}} + \frac{1}{10^{\text{pH}_n}}} \\ n$$

Mean pH did not vary greatly. The waters were slightly alkaline with zonal averages ranging between 7.3 and 8.1 (Table 7).

TABLE 7 pH IN SHUSHAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION	JUNE			SEPTEMBER			STATION	NOVEMBER		
	n	Range	Mean	n	Range	Mean		n	Range	Mean
A 1-11 EPI*	19	7.7-8.1	7.9	22	7.7-7.9	7.8	1-11 ISO	22	7.5-7.7	7.6
HYP	19	7.6-8.0	7.8	18	7.4-7.9	7.6				
B 12-17,							13-16 ISO	8	7.4-7.6	7.6
21-30 EPI	32	7.7-8.0	7.8	32	7.6-7.8	7.7				
HYP	32	7.6-8.0	7.8	32	7.2-7.8	7.4				
C 31-33 EPI	6	7.5-7.9	7.7	6	7.3-7.7	7.6				
HYP	6	7.5-7.8	7.6	6	7.3-7.7	7.4				

1979

ZONE & STATION	APRIL			JUNE			AUGUST			OCTOBER		
	n	Range	Mean	n	Range	Mean	n	Range	Mean	n	Range	Mean
A 1-3 EPI	6	8.0-8.1	8.0	22	7.4-8.3	7.7	22	7.9-8.4	8.1	22	7.7-7.8	7.8
HYP	6	8.1-8.2	8.1	22	7.3-7.7	7.5	22	7.3-8.1	7.4	19	7.3-7.6	7.5
ISO	32	7.9-8.0	7.9									
B												
				2	7.3-7.6	7.4	2	8.1	8.1	2	7.8	7.8
				2	7.3	7.3	2	7.6	7.6	2	7.5	7.5
16 ISO	4	7.9	7.9									

* EPI = Epilimnion
HYP = Hypolimnion
ISO = Isothermal

Notably, the difference between epilimnetic and hypolimnetic pH values was greatest in the late summer (August) when phytoplankton biovolume in Shuswap Lake was highest (Section 4.2.3.1, Table 12). Generally as the phytoplankton growing season progresses, photosynthetic activity increases in the epilimnion which results in an increase in oxygen (O_2) levels and a decrease in carbon dioxide (CO_2) levels. Consequently the pH increases when CO_2 is taken up by the algae at a faster rate than it can be replaced through atmospheric CO_2 diffusion, respiration, or readjustment of solid carbonate equilibrium. With the increase in phytoplankton growth in the epilimnion, there is a subsequent increase in organic degradation in the hypolimnion; the decrease in O_2 levels and increase in CO_2 levels, lowers the pH. Therefore, with increasing phytoplankton productivity in a system, the difference between epilimnetic and hypolimnetic pH values can increase (Wetzel, 1975).

4.2.2.2 Oxygen (percent saturation). The degree of oxygen saturation can be affected by primary productivity. While not a direct measure of primary productivity, phytoplankton biovolume, does measure the standing crop of primary producers and can be used to indicate the trophic status of a lake. When phytoplankton primary productivity (as indicated by increased biovolumes) increases, the photosynthetic activity in the water increases and oxygen levels increase. The epilimnion became saturated or near saturated during the phytoplankton growing season. As early as April in 1979, when there was already a noticeable increase in phytoplankton biovolume, the epilimnion in Zone A at Stations 1-3 was saturated (Table 8). Supersaturations in the epilimnion corresponded with periods of increased productivity, ie. June and August (Figure 11).

In all zones, oxygen saturation decreased in the hypolimnion from summer to fall and the difference between epilimnetic and hypolimnetic oxygen values increased during this period. As the growing season progressed, more phytoplankton died off and sank along with other detritus; decomposition increased below the thermocline and oxygen levels decreased correspondingly.

TABLE 8 OXYGEN (PERCENT SATURATION) IN SHUSHAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION	JUNE			SEPTEMBER		
	n	Range	Mean S. Dev.**	n	Range	Mean S. Dev.
A 1-11 EPI*	19	88.34-114.82	103.78 6.73	14	91.44-103.14	97.93 2.96
	18	76.51-92.92	85.73 5.37	11	72.71-83.75	79.99 3.20
B 12-17, EPI	32	91.08-115.67	103.56 5.55	31	94.38-101.62	98.30 2.10
	32	75.69-90.17	84.41 3.25	32	62.36-88.32	82.48 6.19
C 31-33 EPI	5	105.24-107.56	106.67 0.86	5	99.43-101.49	100.40 0.55
	4	83.54-86.09	84.38 1.00	6	76.91-86.75	84.56 3.50

1979

	APRIL			STATION	JUNE			AUGUST			OCTOBER								
	n	Range	Mean S. Dev.		n	Range	Mean S. Dev.	n	Range	Mean S. Dev.	n	Range	Mean S. Dev.						
A 1-3	EPI	6	92.05-107.83	100.84	4.96	1-11	EPI	22	92.89-135.27	110.31	10.08	22	105.85-133.56	121.22	6.80	22	89.69-97.89	93.11	2.31
	HYP	6	76.32-87.98	79.65	4.35		HYP	22	78.78-103.33	87.74	5.34	22	74.72-94.3	85.83	5.19	19	48.54-78.35	69.86	8.01
4-11	ISO	22	81.75-101.73	96.91	4.75														
B						16	EPI	2	02.47-132.35	117.41	21.31	2	118.0-120.79	119.40	1.97	2	93.78-94.22	94.0	0.31
							HYP	2	88.35-94.12	91.24	4.08	2	84.97-91.22	88.10	4.42	2	75.51-79.17	77.34	2.59
16	ISO	4	95.04-95.78	95.29	0.29														

* EPI = epilimnion
HYP = hypolimnion

ISO = isothermal
**S. Dev. = standard deviation

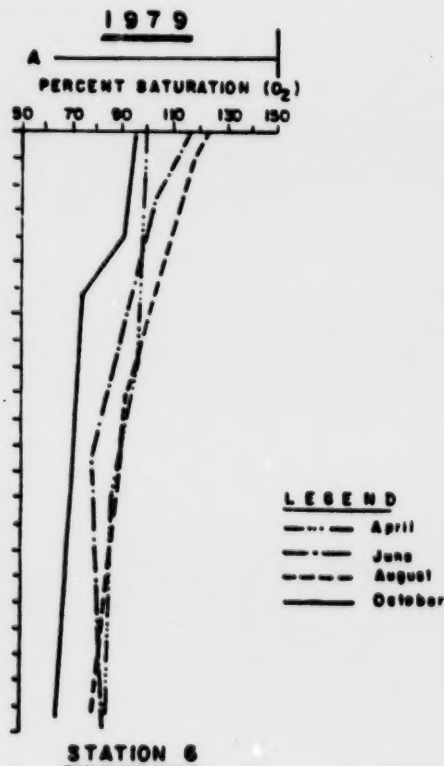
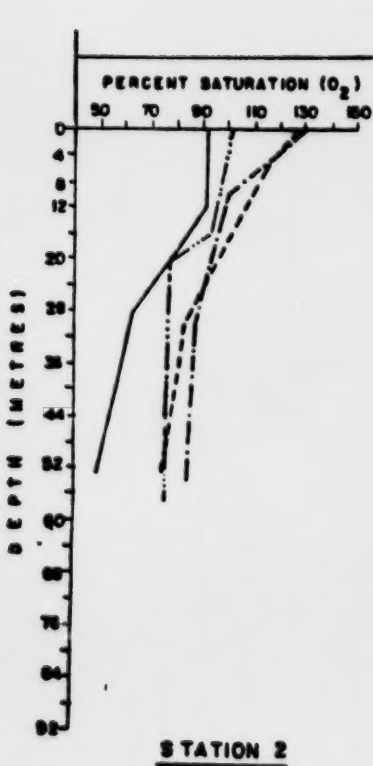
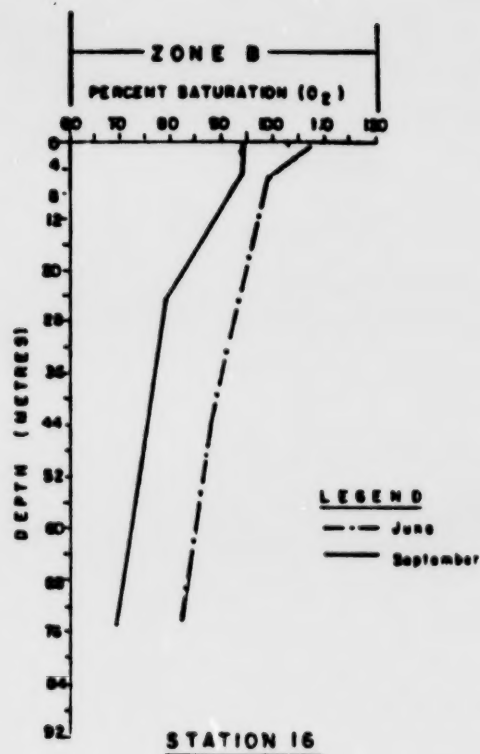


FIGURE 11 PERCENT SATURATION OF OXYGEN AT REPRESENTATIVE SITES IN SHUSWAP LAKE DURING 1978 AND 1979

4.2.2.3 Conductivity. Since conductivity is proportional to total dissolved solids (Wetzel, 1975), the decrease in conductivity from Zone A to Zone C (Figure 12) implies a respective decrease in total dissolved solids. Both the Salmon River and the Salmon Arm sewage treatment plant may be responsible for the greater total dissolved solid levels and therefore, the higher conductivity in Zone A. Zone C had the lowest conductivity where major rivers or anthropogenic sources contributed to total dissolved solid levels.

The highest conductivities throughout the study were recorded in the hypolimnion at the three stations nearest to the STP (1 to 3) in Zone A in April 1979. During the sampling period, Salmon River flows were at their lowest and the STP continued to discharge at its average annual rate. By mid-April, stations 1 to 3 were the only stations that had started to stratify thereby preventing free mixing of the water column. Total dissolved solids from possibly both the Salmon River and the STP may have settled and become trapped below the forming thermocline to increase conductivity levels.

The small decrease in conductivity in each zone from spring to fall is possibly a reflection of a decrease in allochthonous loadings.

4.2.2.4 Phosphorus. Phosphorus levels decreased from Zone A through to Zone C (Figures 13 and 14). Two major sources of phosphorus loading, the Salmon Arm sewage treatment plant and the Salmon River, empty into Zone A. In contrast, no major rivers empty into Zone C and the shores are sparsely populated.

Along with zonal variation, seasonal variation in phosphorus levels occurred. In Zone A total phosphorus levels in the epilimnion decreased over the summer with phytoplankton biovolume increases. However by late summer or early fall phosphorus levels in Zone B and C had remained the same or increased.

Previous studies have pointed out that using ambient and loading models to predict the trophic state of a lake is not entirely satisfactory.

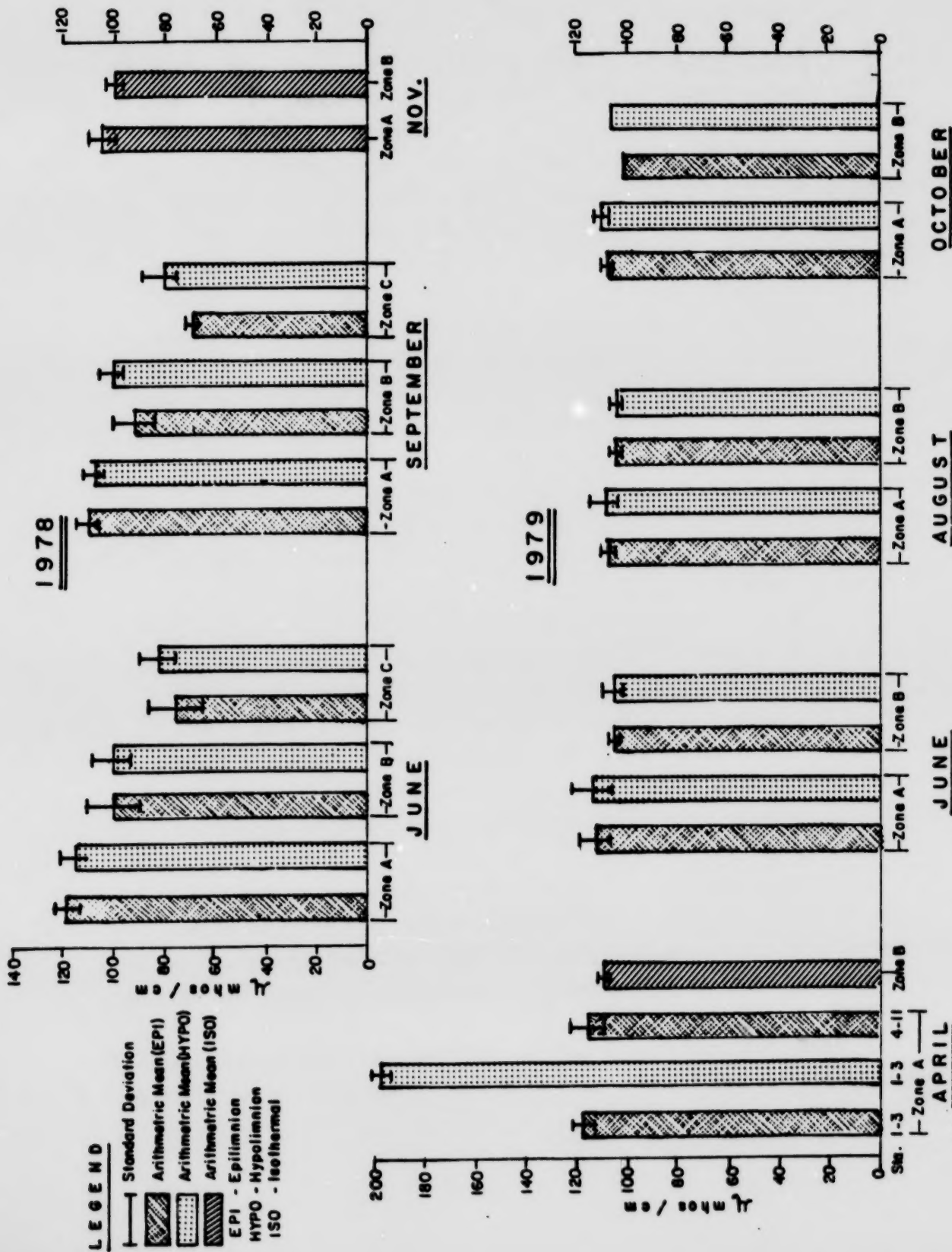


FIGURE 12 CONDUCTIVITY READINGS IN SHUSWAP LAKE DURING 1978 AND 1979

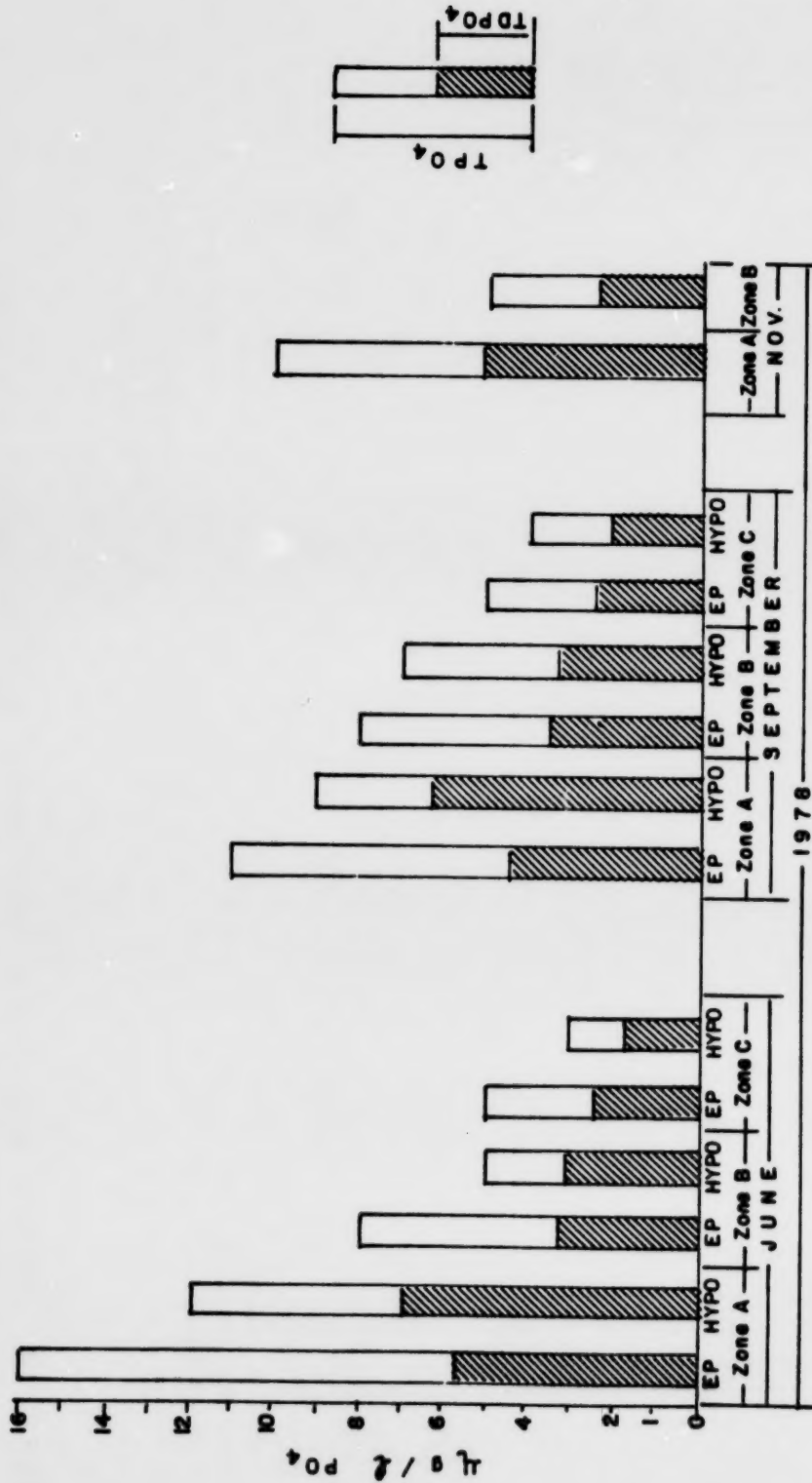


FIGURE 13 TOTAL AND DISSOLVED MEAN PHOSPHORUS CONCENTRATIONS IN SHUSWAP LAKE DURING 1978

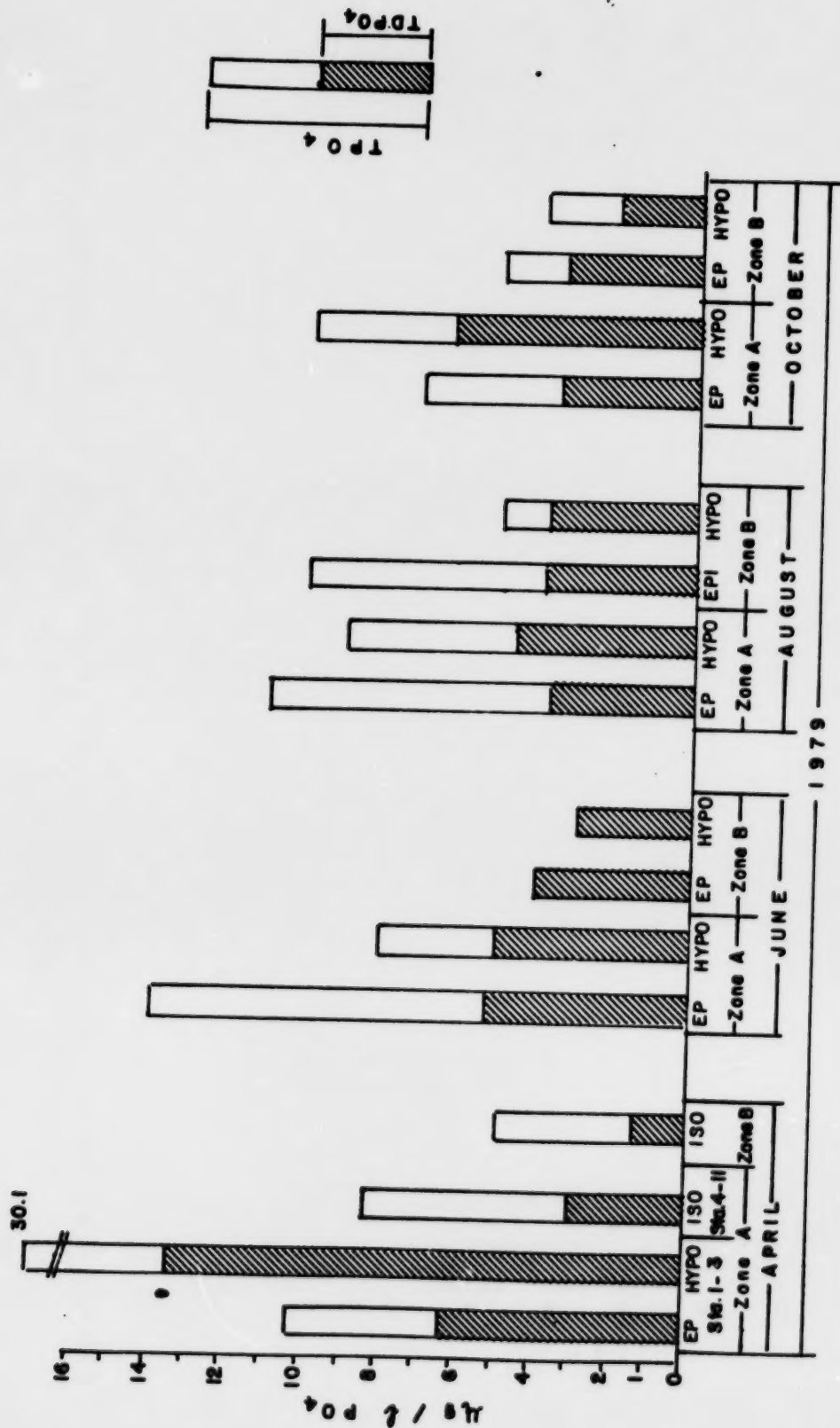


FIGURE 14 TOTAL AND DISSOLVED MEAN PHOSPHORUS CONCENTRATIONS IN SHUSWAP LAKE DURING 1979

Use and incorporation of phosphorus into phytoplankton biomass varies significantly from lake to lake depending on availability of light, sufficient supply of other nutrients and biological availability of various phosphorus species (Hern, et al, 1981). However, general relationships can be used to highlight differences between zones. Wetzel (1975) categorized the trophic type of lakes according to general ranges of various limnological characteristics including total phosphorus (Table 9). The epilimnetic total phosphorus values for June 1978, and June and August 1979 in Shuswap Lake suggest Zone A was mesotrophic to meso-eutrophic, Zone B was oligotrophic to oligo-mesotrophic, and Zone C was oligotrophic. Eutrophication appeared more advanced in Zone A than B or C.

4.2.2.5 Nitrate/Nitrite Nitrogen. Nitrate-nitrite concentrations are considered more a reflection of nitrate levels than nitrite levels because of the very low nitrite concentrations found in freshwater (Wetzel, 1975). There can be a significant drop in levels with an increase in phytoplankton production because nitrate is readily assimilated by algae. In June and September 1978, nitrate levels in both the epilimnion and hypolimnion increased from Zone A to Zone C (Figures 15 and 16) perhaps a reflection of a respective decrease in phytoplankton productivity as measured by biovolume. By September 1978, after the summer growing season, the epilimnetic values had decreased in all the zones. The epilimnetic values in Zone A and B were reduced to less than the 2 ug/l detection limit. By November 1978, under isothermal conditions and low primary production, Zone A and Zone B mean nitrate concentrations had increased to approximately 73 ug/l.

In April 1979, mean nitrate concentrations at Stations 4 to 11 in Zone A and at Station 16 in Zone B were similar. However, at Stations 1 to 3 in Zone A, where phytoplankton biovolume had increased, the epilimnetic value had already dropped to 42.6 ug/l and nitrate levels had built up in the hypolimnion to a mean concentration of 142.8 ug/l.

TABLE 9 GENERAL RANGES OF VARIOUS LIMNOLOGICAL CHARACTERISTICS OF LAKES OF DIFFERENT TROPHIC CATEGORIES

TROPHIC TYPE	PHYTOPLANKTON BIOVOLUME (cm ³ /m ³)	CHLOROPHYLL A (mg/m ³)	DOMINANT PHYTOPLANKTON	TOTAL P (ug/l)	TOTAL N (ug/l)
Ultra-oligotrophic Oligotrophic	1	0.01-0.05 0.3-3	Chrysophyceae Cryptophyceae	1-5	1-250
Oligo-mesotrophic	1-3		Dinophyceae Bacillariophyceae	5-10	250-600
Mesotrophic Meso-eutrophic Eutrophic	3-5	2-15 10-500	Bacillariophyceae Cyanophyceae Chlorophyceae Euglenophyceae	10-30 30-5000	500-1100 500-15000
Hypereutrophic Dystrophic	10	0.1-10		1-10	1-500

*Modified from Wetzel (1975), after many authors and sources

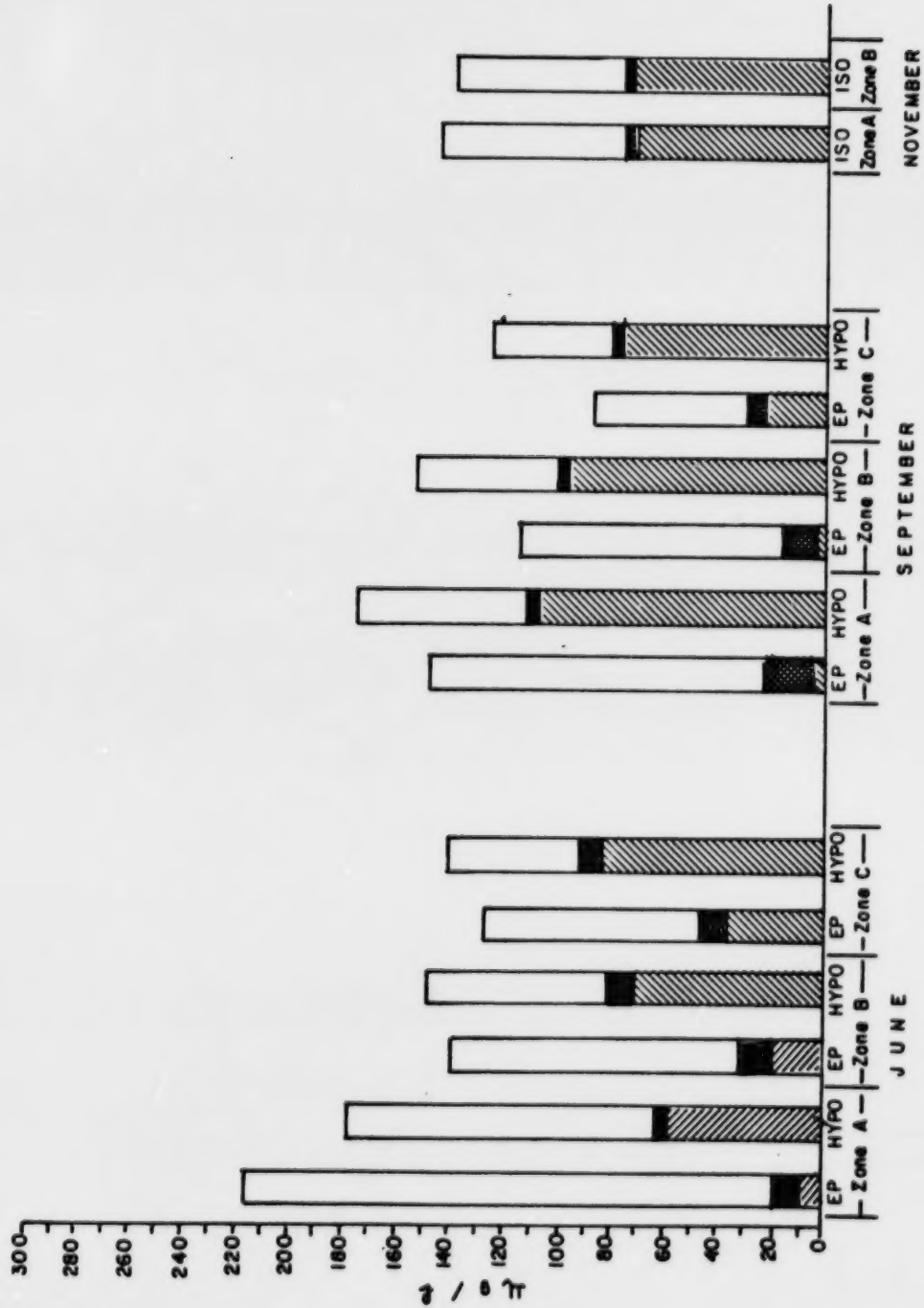


FIGURE 15 MEAN NITROGEN CONCENTRATIONS IN SHUSWAP LAKE DURING 1978

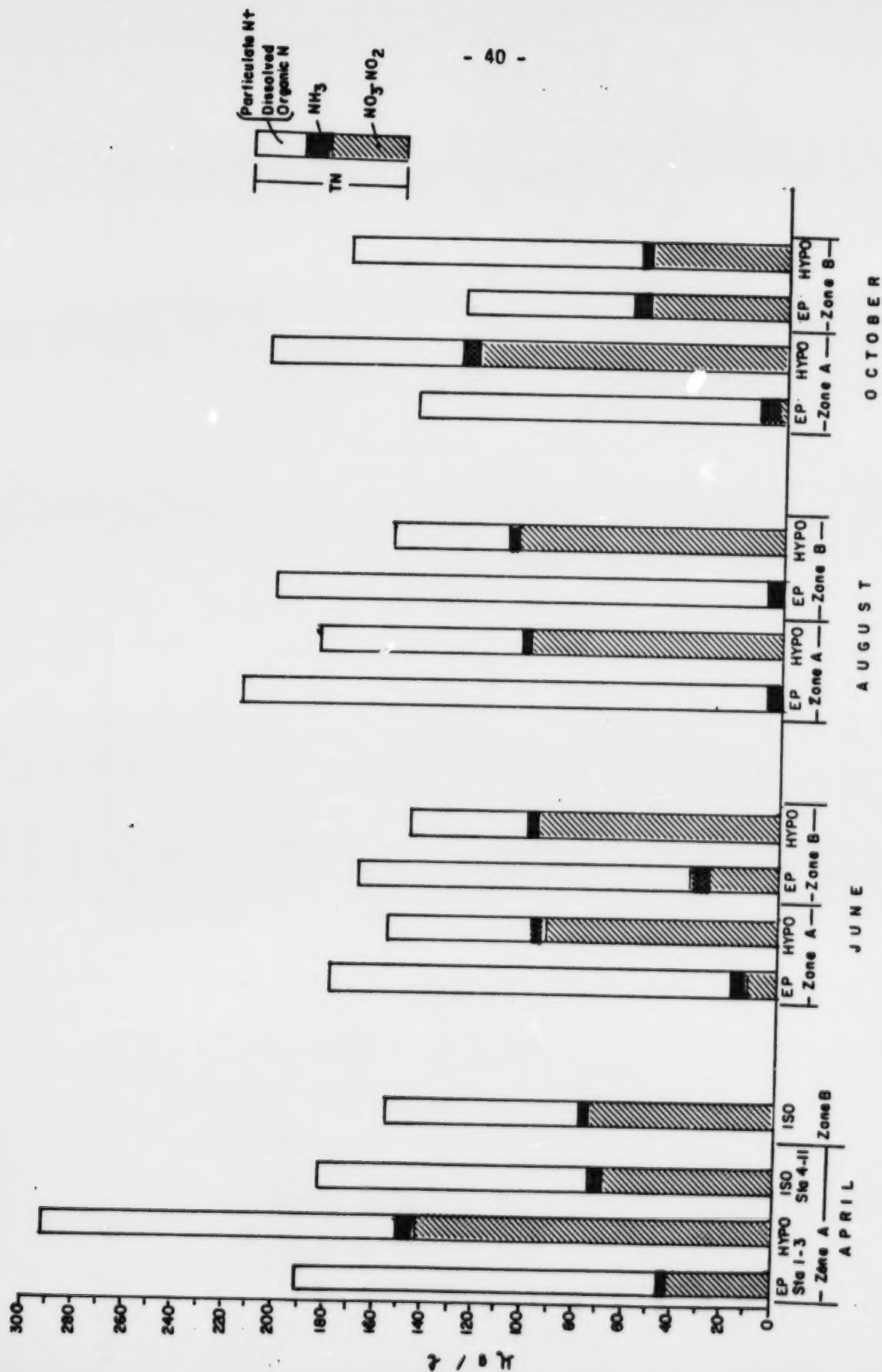


FIGURE 16 MEAN NITROGEN CONCENTRATIONS IN SHUSWAP LAKE DURING 1979

In June 1979, after there had already been a major increase in phytoplankton biovolume in Zone A, the epilimnetic mean nitrate concentration in Zone A was about half that of Zone B. In August 1979, at the end of the phytoplankton growing season, the mean epilimnion values in both Zone A and B had decreased to below the detection limit of 2 ug/l, but the hypolimnetic values continued to increase to over 100 ug/l.

Nitrate levels were lowest in the epilimnion in late summer, at the end of the growing season, as a result of uptake of nitrate by the algae. Zone C had the lowest phytoplankton biovolume and the highest nitrate levels possibly because there were less nutrients being utilized by the smaller algal population.

Nitrate can be trapped below the thermocline when a lake is stratified. Dying algae and other detritus sink to the hypolimnion where they decompose and add to the nitrogen pool. Nonetheless, hypolimnetic nitrate values appear to be unusually high in Zone A in October. Perhaps input of nitrate from allocthonous sources such as the Salmon River and Salmon Arm sewage treatment plant contribute to the high levels.

4.2.2.6 Ammonia Nitrogen. Ammonia (NH_3) levels did vary significantly between zones or from month to month (Figures 15 and 16). However, ammonia levels in the epilimnion of Zone A decreased by almost half from early summer (June) to late summer (August), when phytoplankton populations increased. By fall (September 1978; October 1979) ammonia levels doubled in the epilimnion of Zone A again. The sewage treatment plant discharge and agricultural runoff, via the Salmon River, provided a continued supply of ammonia in the late summer and fall. Little NH_3 was utilized by algae after the phytoplankton population had declined so NH_3 levels increased over the winter. Comparatively, there was little fluctuation in ammonia levels in Zone B.

4.2.2.7 Nitrogen/Phosphorus Ratio. Waters having a total nitrogen: total phosphorus ratio by weight of greater than 15 to 17 are considered

phosphorus limiting while waters with a N:P ratio of less than 9 to 10 are nitrogen limiting. In waters having a N:P ratio of 9 to 15, nitrogen and phosphorus concentrations are nearly balanced with the ratio required for phytoplankton growth (Sakamoto, 1966). Shuswap Lake appears to be phosphorus limiting with a N:P ratio greater than 15 to 17 throughout most of the year (Table 10). The N:P ratio was between 9 to 15 in Zone A on four occasions: June, September and November 1978 and June 1979; and the N:P ratio was never less than 9 to 10. Therefore, Shuswap Lake does not appear to be nitrogen limiting.

4.2.2.8 Particulate Carbon/Particulate Nitrogen Ratio. The PC:PN ratio is used to indicate whether the major source of carbon for a lake is autochthonous or allochthonous. Autochthonous organic matter is produced by decomposition of plankton within the lake and contains about 24% crude protein with a C:N ratio of about 12:1 (Wetzel, 1975). Allochthonous organic matter has most of the N removed and contains about 6% crude protein with a C:N ratio of 45:1 to 50:1 (Hutchinson, 1957).

The epilimnetic C:N ratio for Zones A, B, and C in both 1978 and 1979 were all less than or equal to 12:1 suggesting that Shuswap Lake's major source of organic matter is from within the lake itself by decomposition of plant and animal material (Table 11).

4.2.2.9 Silicon Dioxide. Silicon dioxide concentrations in Shuswap Lake were comparable to other B.C. lakes such as Okanagan Lake where the range was between 3.5 to 5.3 mg/l (Truscott & Kelso, 1979), and Kamloops Lake where the annual range was from 4.0 to 6.9 mg/l (St. John et al, 1976).

Silicon dioxide in epilimnetic waters ranged from an average of 3.5 mg/l for Zone B at Station 16 in August 1979 to an average of 7 mg/l for Zone A in June 1978 (Figure 17). As expected, the concentrations were lowest during the late spring and summer when silicon dioxide was utilized by diatoms.

TABLE 10 TOTAL NITROGEN:TOTAL PHOSPHORUS RATIO BY WEIGHT IN SHUSHAP LAKE DURING 1978 AND 1979

ZONE	1978			1979			
	JUNE (epilimnion)	SEPTEMBER (epilimnion)	NOVEMBER (isothermal)	STATION	APRIL	JUNE (epilimnion)	AUGUST (epilimnion) OCTOBER (isothermal)
A	14:1	13:1	13:1	1-3 4-11	17:1 22:1	1-11 13:1	26:1 22:1
B	18:1	17:1	30:1	16	32:1	16 40:1	21:1 25:1
C	26:1	36:1	--				

TABLE 11 PARTICULATE CARBON:PARTICULATE NITROGEN RATIO BY WEIGHT IN SHUSWAP
LAKE DURING 1978 AND 1979

		1 9 7 8			1 9 7 9			
ZONE		JUNE	SEPT.	NOV.	APRIL	JUNE	AUG.	OCT.
A	EPI	8:1	8:1	9:1	8:1	10:1	9:1	9:1
B	EPI	9:1	8:1	10:1	10:1	4:1	9:1	9:1
C	EPI	12:1	9:1	--				

NOTE: See Table 22 for Particulate Carbon Results and Table 18 for Particulate
Nitrogen Results

EPI = epilimnion

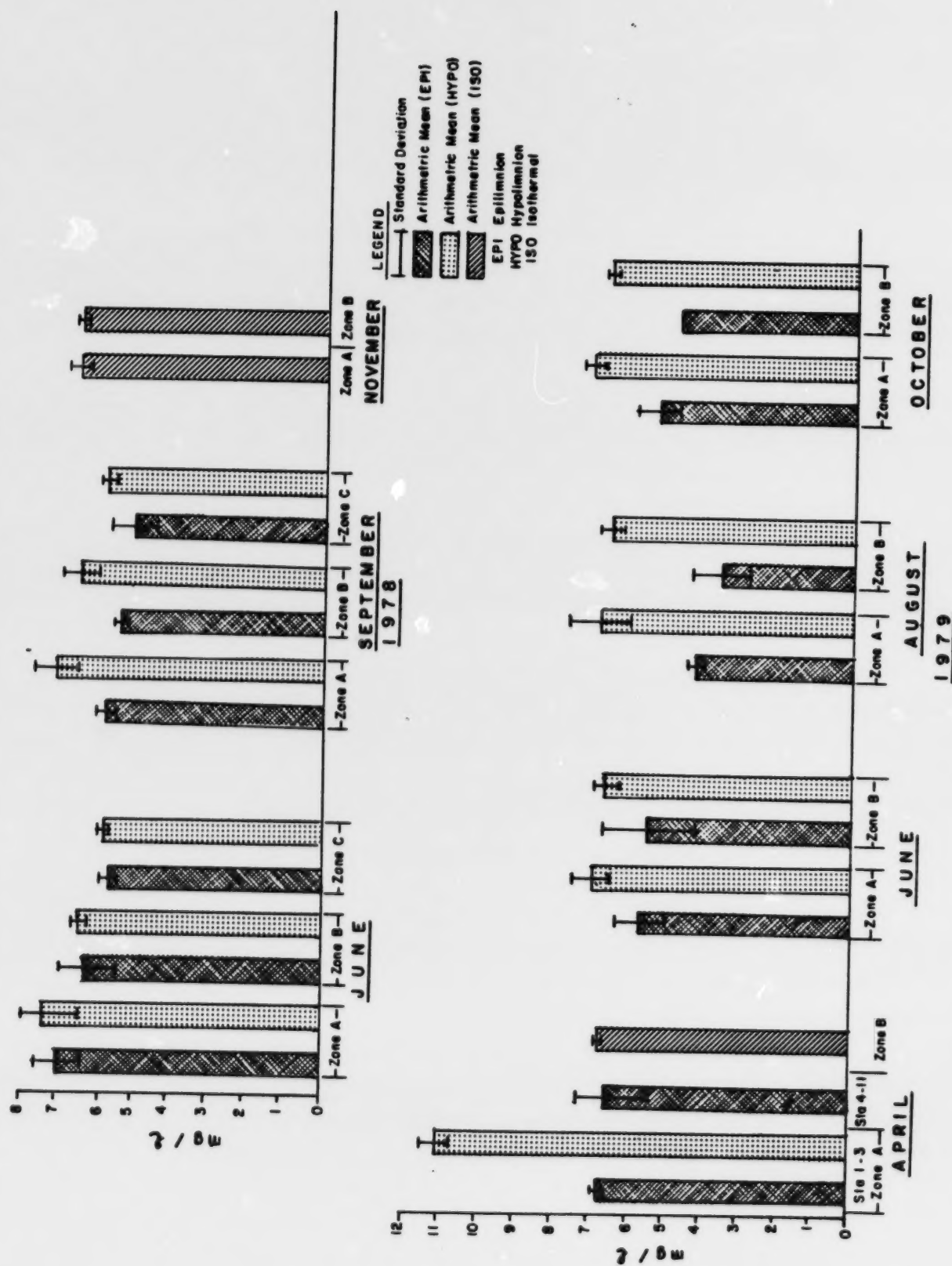


FIGURE 17 MEAN SILICA DIOXIDE CONCENTRATIONS IN SHUSWAP LAKE DURING 1978 AND 1979

4.2.3 Biological Characteristics.

4.2.3.1 Phytoplankton. A decrease in phytoplankton biovolume (Table 12), indicates a shift in trophic status from Zone A to Zone C according to Wetzel's (1975) categorization (Table 9). Phytoplankton biovolumes in June 1978 and August 1979 suggest Zone A was mesotrophic to meso-eutrophic, Zone B was oligo-mesotrophic and Zone C was ultra-oligotrophic to oligotrophic. This trophic categorization of the three study zones based on phytoplankton biovolume corresponds with the categorization based on total phosphorus concentrations (Section 4.2.2.4).

Phytoplankton biovolume decreased in all three zones between June 1978 and September 1978 (Figure 18). After the summer algal bloom, the phytoplankton population declined when nutrients were depleted. The population then remained low because of light/temperature limiting factors.

In April 1979, phytoplankton biovolume at Stations 1 to 3 in Zone A was already high and was comparable to the Zone A average phytoplankton biovolume in June 1979. Phytoplankton biovolume at Stations 4 to 11 in April 1979 was approximately one-half of the average June Zone A average biovolume.

Phytoplankton in Zone A continued to increase from early summer 1979 (June) to late summer (August) possibly because of increased anthropogenic nutrient sources, then declined sharply in the fall (October) when light and temperature were limiting. Phytoplankton biovolume in Zone B peaked in early summer (June) and had already declined by late summer (August) possibly because of lack of nutrients.

The shift in the major algal groups from Zone C to Zone A (Figure 19) also reflects a shift from oligotrophy to meso-eutrophy or eutrophy. As oligotrophic conditions become eutrophic, there is a shift in the dominant phytoplankton populations from Chrysophyceae, Cryptophyceae,

TABLE 12 MEAN PHYTOPLANKTON BIOVOLUME (cm^3/m^3) FOR SHUSHAP LAKE IN 1978 AND 1979

1978

ZONE & STATION		JUNE	SEPTEMBER	STATION	NOVEMBER
A	1-11	3.30	0.66	1-11	0.61
B	12-17, 21-30	1.42	0.45	13,16	0.52
C	31-33	0.79	0.26		NS

1979

ZONE & STATION		APRIL	STATION	JUNE	AUGUST	OCTOBER
A	1-3 4-11	2.73 1.57	1-11	2.63	3.06	0.42
B	16	0.41	16	3.27	1.18	0.51

NS = not sampled

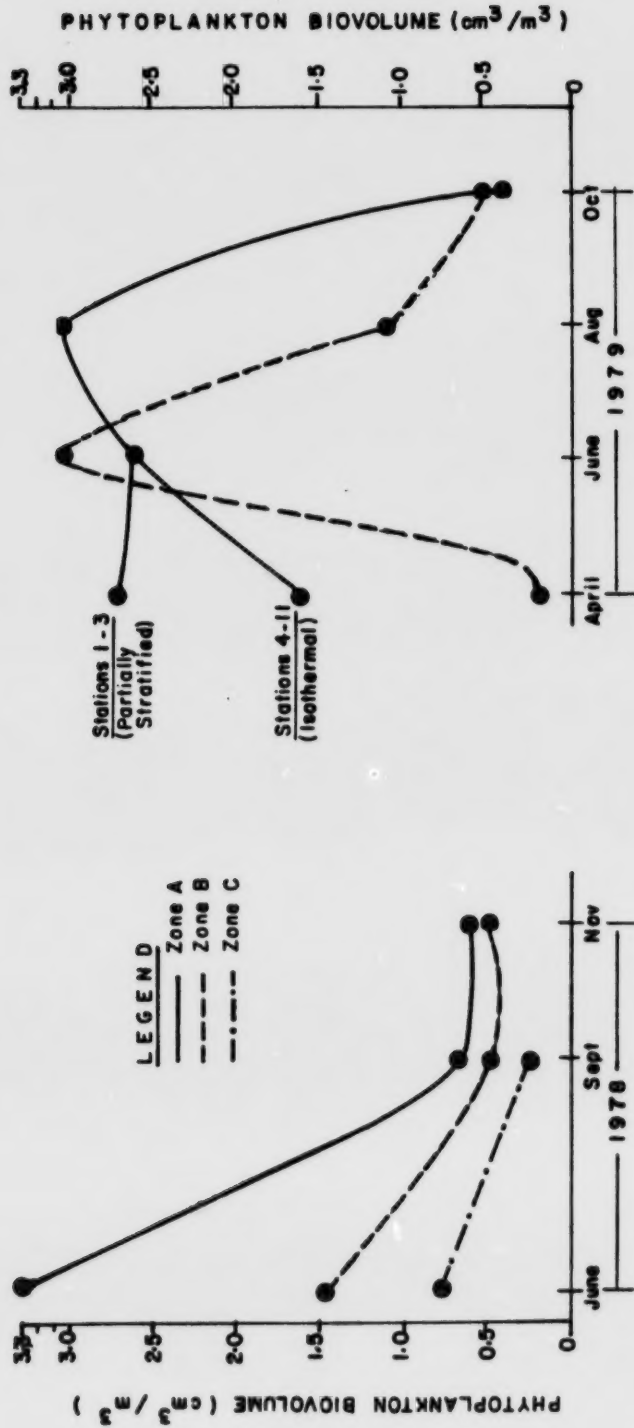


FIGURE 18 PHYTOPLANKTON BIOVOLUME IN SHUSWAP LAKE DURING 1978 AND 1979

Dinophyceae and Bacillariophyceae to Bacillariophyceae, Cyanophyceae, Chlorophyceae and Euglenophyceae.

In Zone A (Table 13), cryptomonads predominated only in the spring (April 1979). Diatoms (Bacillariophyceae) and blue-green (Cyanophyceae) dominated during the summer and fall. In Zone B (Table 14), cryptomonads predominated only in the spring (April 1979). Diatoms and dinoflagellates (Dinophyceae) dominated during the summer and fall. Blue-greens did not make up more than 40% of the total population until the late summer (August 1979) and fall (October 1979). By early winter (November 1978) diatoms predominated again. In Zone C (Table 15), diatoms dominated in the summer (June 1978) and fall (September 1978). Chrysophytes, often associated with oligotrophic waters, were abundant in the summer; cryptomonads, also associated with oligotrophic waters, were abundant in the fall.

Individual genera and/or species of algae can indicate the trophic status of a lake (Hutchinson, 1967). Three dominant genera were found to constitute between 50% to 80% of the total phytoplankton biovolume in each zone (Figure 20 and 21). Plankton often associated with eutrophic lakes and that were among the dominant algae in Zone A and B were Fragilaria crotonensis, Synedra spp., and Anabaena (Round, 1973). However, the biovolumes of these algae were greater in Zone A than Zone B. Surirella ovata, Synedra delicatissima, and Asterionella formosa were all prominent algal species in Zone A and are also associated with eutrophic waters (Palmer, 1977).

Cyclotella comta, the prominent alga found in Zone C in June and September 1978, is the dominant alga most often found in oligotrophic lake water (Wetzel, 1975).

The chlorophyll-a values (Table 16) cannot be compared with values from other lakes because an error was made in the chlorophyll analysis. However, the error was consistent; therefore, the values can be used qualitatively to compare between zones within Shuswap Lake.

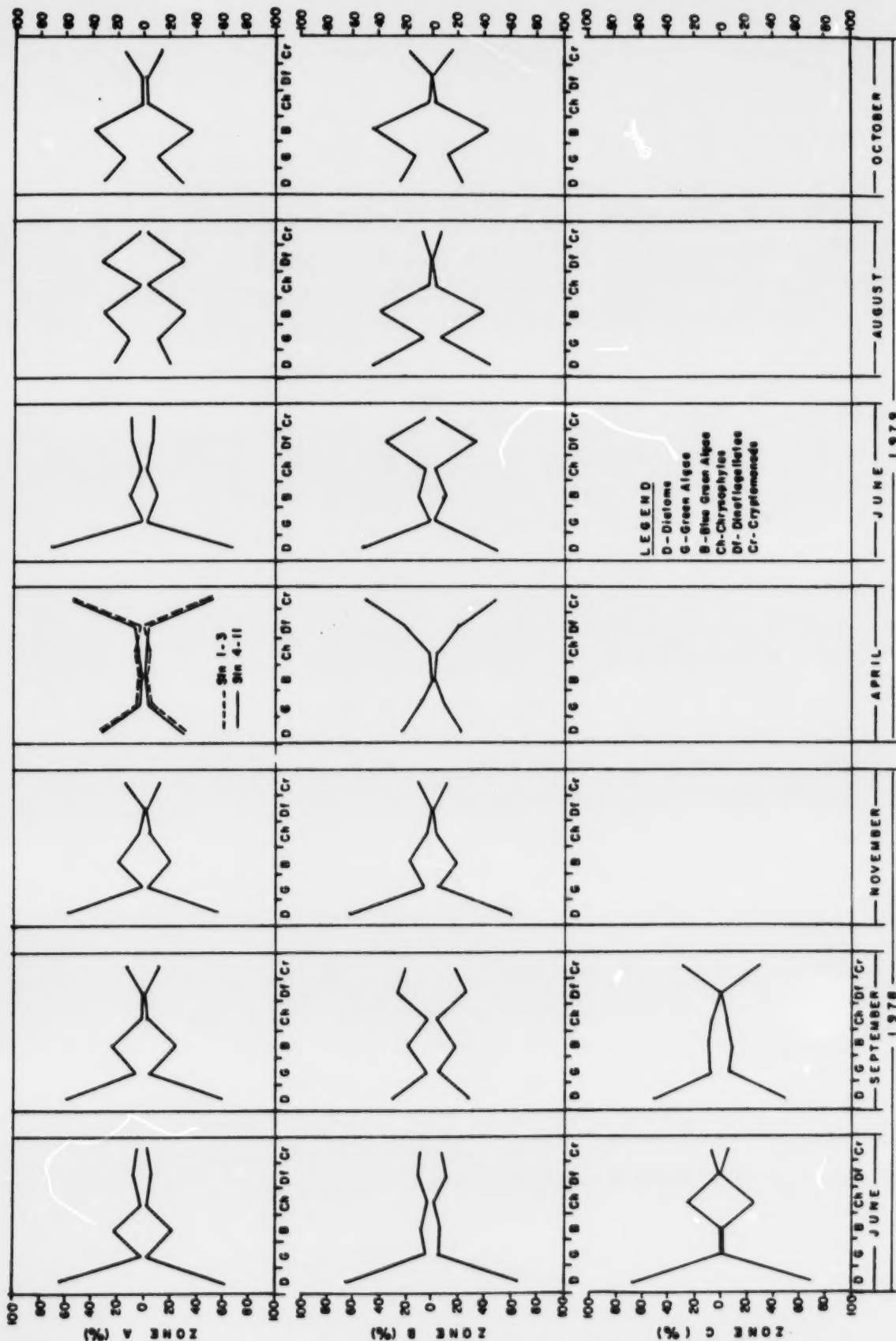


FIGURE 19 PERCENT COMPOSITION BY VOLUME OF MAJOR ALGAL GROUPS IN SHUSWAP LAKE DURING 1978 AND 1979

TABLE 13 MEAN PHYTOPLANKTON BIOVOLUMES (cm^3/m^3) AND PERCENT COMPOSITION OF MAJOR ALGAL GROUPS IN ZONE A DURING 1978 AND 1979

	June 1978		Sept., 1978		Nov., 1978		April 1979*		June 1979		Aug., 1979		Oct., 1979	
	Volume	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
Diatoms	2.29	63.7	0.39	59.6	0.37	58.3	0.97	35.0	1.92	69.4	0.71	21.5	0.13	30.9
(Bacillariophyceae)							0.55	33.3						
Green Algae	0.03	0.7	0.03	4.0	0.02	3.3	0.18	6.5	0.05	1.7	0.37	11.3	0.06	13.6
(Chlorophyta)							0.09	5.7						
Blue-Green Algae	0.76	21.1	0.15	23.1	0.13	20.4	0.07	2.5	0.28	0.10	1.04	31.6	0.16	37.5
(Cyanophyta)							0.02	0.9						
Chrysophytes	0.06	1.6	0.004	0.5	0.03	4.0	0.16	6.0	0.07	2.6	0.02	0.6	0.009	2.0
(Chrysophyta)							0.05	2.8						
Dinoflagellate	0.29	8.1	0	0	0.0005	0.1	0.02	0.8	0.21	7.7	1.06	32.1	0.0006	0.1
(Pyrrhophyta)							0.10	6.2						
Cryptomonads	0.17	4.7	0.08	12.7	0.09	13.9	1.36	49.2	0.24	8.6	0.10	2.9	0.07	16.0
(Cryptophyta)							0.84	51.0						
TOTAL	3.60	100	0.65	100	0.64	100	2.76	100	2.77	100	3.30	100	0.43	100
							1.65	100						

*For April 1979 the average phytoplankton biovolume of each major algal group was calculated for Stations 1-3 (first number under each grouping) and for Stations 4-11 (second number under each grouping).

TABLE 14 MEAN PHYTOPLANKTON BIOVOLUMES (cm^3/m^3) AND PERCENT COMPOSITION OF MAJOR ALGAL GROUPS IN ZONE B DURING 1978 AND 1979

	June 1978		Sept. 1978		Nov. 1978		April 1979*		June 1979		Aug. 1979		Oct. 1979	
	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
Diatoms	1.01	65.5	0.17	29.3	0.32	62.2	0.10	22.7	2.13	47.5	0.53	45.1	0.12	23.6
(Bacillariophyceae)														
Green Algae	0.08	5.1	0.02	3.9	0.03	5.4	0.04	8.2	0.03	0.8	0.07	5.9	0.07	12.9
(Chlorophyta)														
Blue-Green Algae	0.11	7.2	0.10	17.5	0.10	18.4	0	0	0.38	8.4	0.47	39.5	0.22	43.6
(Cyanophyta)														
Chrysophytes	0.03	1.7	0.02	3.9	0.01	2.9	0.006	1.4	0.12	2.7	0.04	3.3	0.007	1.5
(Chrysophyta)														
Dinoflagellate	0.17	10.7	0.15	26.2	0	0	0.09	19.8	1.61	36.0	0	0	0	0
(Pyrrhophyta)														
Cryptomonads	0.15	9.7	0.11	19.2	0.06	11.2	0.21	47.9	0.20	4.5	0.07	6.3	0.09	18.4
(Cryptophyta)														
TOTAL	1.55	100	0.57	100	0.52	100	0.45	100	4.47	100	1.18	100	0.51	100

*For April 1979 the average phytoplankton biovolume of each major algal group was calculated for Stations 1-3 (first number under each grouping) and for Stations 4-11 (second number under each grouping).

TABLE 15 MEAN PHYTOPLANKTON BIOVOLUMES (cm^3/m^3) AND PERCENT COMPOSITION OF MAJOR ALGAL GROUPS IN ZONE C DURING 1978 AND 1979

	June 1978		Sept. 1978	
	Value	%	Value	%
Diatoms	0.53	67.9	0.14	51.7
(Bacillariophyceae)				
Green Algae	0.004	0.5	0.02	6.6
(Chlorophyta)				
Blue-Green Algae	0.002	0.2	0.02	8.4
(Cyanophyta)				
Chrysophytes	0.20	24.9	0.01	4.8
(Chrysophyta)				
Dinoflagellate	0	0	0	0
(Pyrrhophyta)				
Cryptomonads	0.05	6.5	0.08	28.5
(Cryptophyta)				
TOTAL	0.79	100	0.27	100

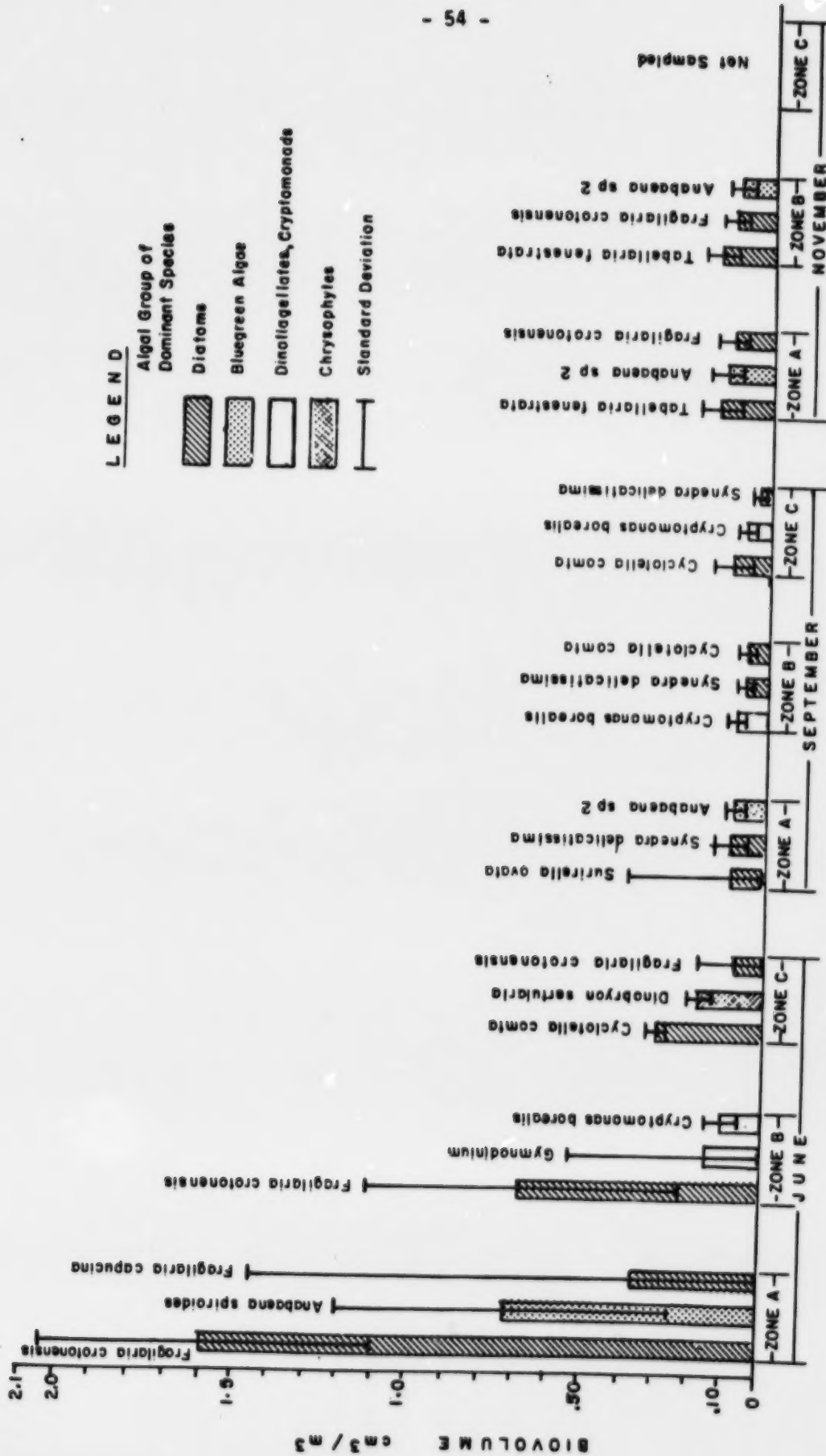


FIGURE 20 MEAN BIOVOLUME FOR THREE DOMINANT PHYTOPLANKTON SPECIES IN SHUSWAP LAKE DURING 1978

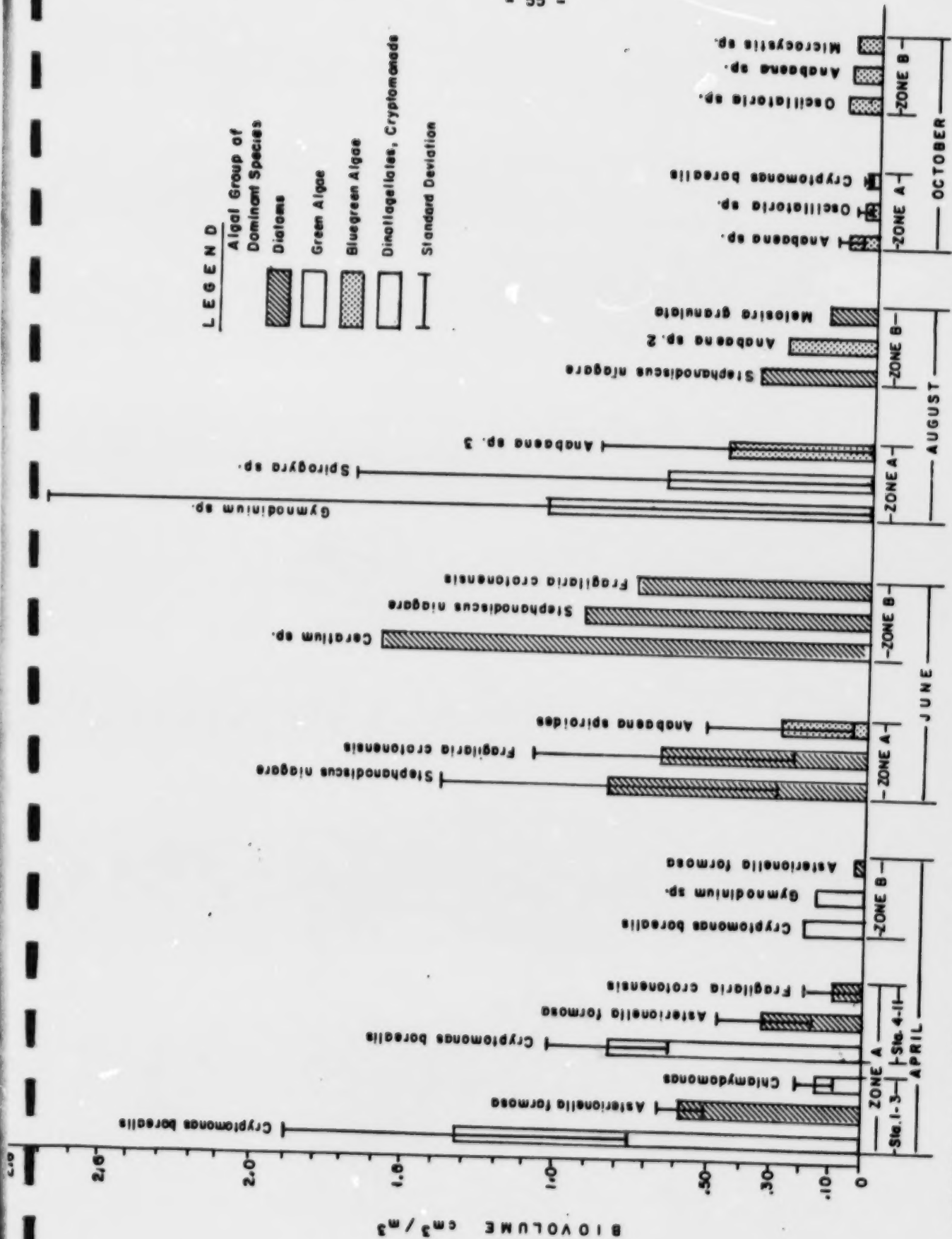


FIGURE 21 MEAN BIOVOLUME FOR THREE DOMINANT PHYTOPLANKTON SPECIES IN SHUSWAP LAKE DURING 1979

TABLE 16 CHLOROPHYLL-a + PHAEOPHYTIN VALUES (mg/m³) IN SHUSHAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION	SEPTEMBER				NOVEMBER			
	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A 1-11	11	2.620-3.620	3.215	0.261	11	3.150-3.570	3.315	0.145
B 12-17 and 21-30	16	1.520-2.170	1.826	0.264	2	2.810-7.020	2.977	4.915
C 31-33	3	1.870-0.006						

1979

ZONE & STATION	JUNE				AUGUST				OCTOBER			
	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A 1-11	11	4.170-8.482	6.587	1.321	11	3.133-17.655	6.824	4.283	11	2.867-4.514		
B 16	1	-	5.904	0	2	-	6.000	0	1	-		

Chlorophyll-a values were twice as high in the summer as they were in the fall. Zone A had the highest chlorophyll-a values throughout the study.

4.2.3.2 Periphyton. Eutrophication of a system as a result of increased nutrient loading is not only reflected by an increase in phytoplanktonic productivity but can also be reflected by an increase in littoral productivity. Development of littoral communities may be a significant part of the eutrophication process in Shuswap Lake because shoreline development is high.

In the initial stages of eutrophication, submerged macrophytes, and phytoplankton are important to total primary productivity. Once the lake is subjected to severe light attenuation, usually associated with intense phytoplankton productivity, emergent vegetation assumes greater dominance in the lake ecosystem. Attached algae (periphyton) develop in strong association with emergent flora. Therefore, in those littoral zones where emergent vegetation is prevalent, larger populations of periphyton are expected.

Stations SA-S1, SA-S2 and SA-S3 were located in Zone A near marshy areas dominated by emergent flora (Figure 7). The shoreline slope was very low allowing for further development of the littoral area. The muddy, silty bottom may have reflected the accumulation of detritus from anthropogenic sources and organic material from decaying plant matter. Station SA-S4 in Zone B served as the control site for the shallow water stations. In contrast to the first three shallow water stations, there were no emergent or submergent macrophytes in the area and periphyton growth was not readily visible on the rocks. Shoreline slope was much greater. The bottom was rocky and the water clear.

Dry weight is often used as an indicator of biological production and is a measure of the standing crop or biomass of periphyton at any given time. However, ash-free dry weight, the organic fraction of the dry weight measurement, is a better estimate of standing crop. Ash-free dry weight was greatest at Station SA-S1 (Figure 22). Both stations SA-S1 and SA-S2,

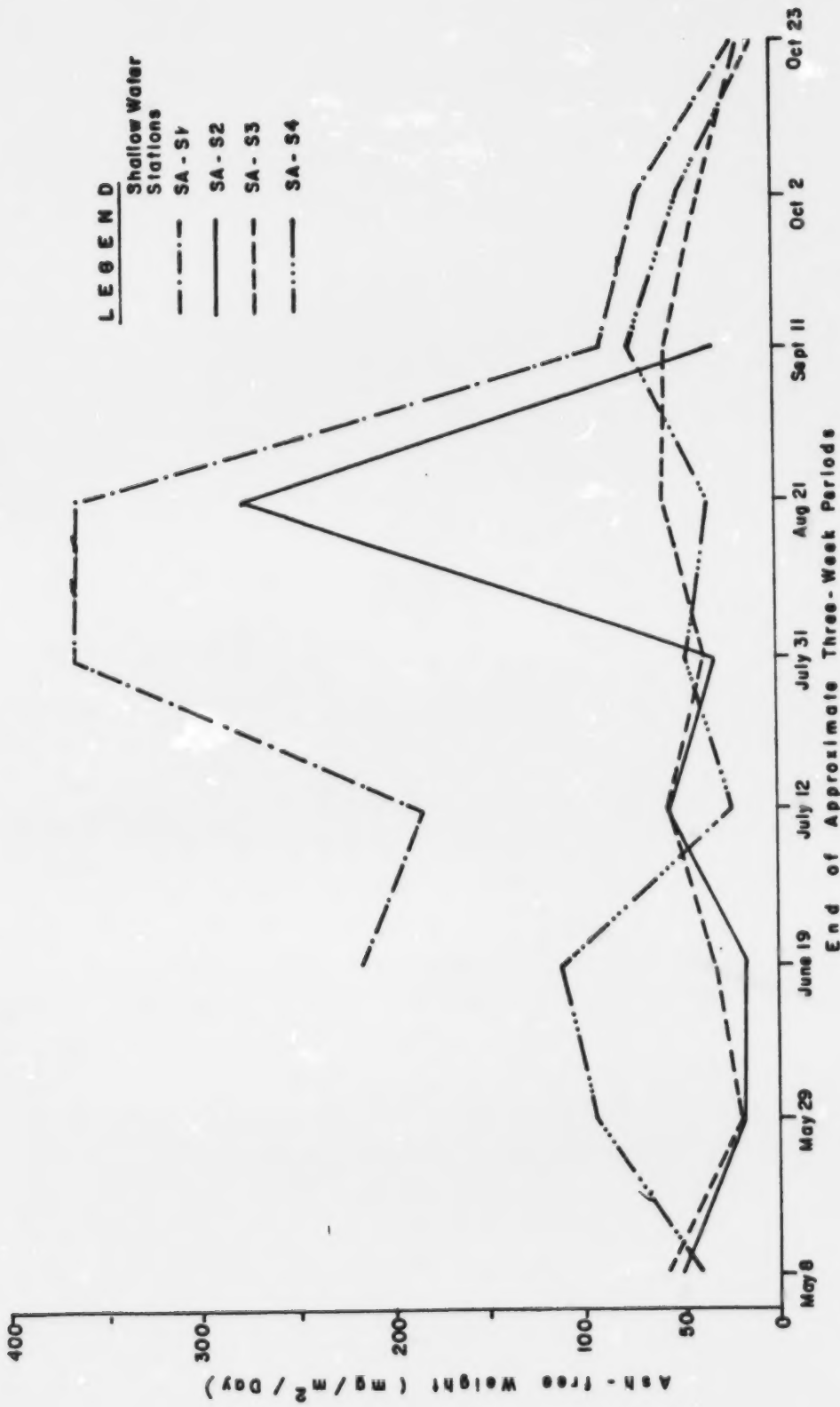


FIGURE 22 PERIPHYTON ASH-FREE WEIGHT AT SHALLOW WATER STATIONS IN SHUSWAP LAKE DURING 1979

the two stations closest to the sewage discharge and Salmon River, had sudden peaks in ash-free weight in mid to late summer. Stations SA-S3 and SA-S4 (control) remained relatively constant throughout the study.

Periphyton biovolume followed much the same pattern as ash-free dry weight measurements (Figure 23). Biovolume peaked in August at all four stations with the least fluctuation in biovolume at Station SA-S4. Generally mean seasonal periphyton biovolume values of over $0.2 \text{ mm}^3/\text{cm}^2$ / three week period are characteristic of eutrophic areas of a lake and seasonal periphyton biovolumes under $0.2 \text{ mm}^3/\text{cm}^2$ are characteristic of oligotrophic to mesotrophic areas (Ennis, 1972). Mean biovolumes did not exceed $0.2 \text{ mm}^3/\text{cm}^2$ (Table 17). However periphyton biovolume at Station SA-S1 ($0.16 \text{ mm}^3/\text{cm}^2$) approached $0.2 \text{ mm}^3/\text{cm}^2$. Mean values decreased from Station SA-S1 to SA-S4 (control).

The late summer algal assemblages at all four stations were dominated by the chlorophytes, Ulothrix and Spirogyra. Cladophora was prevelant at Stations SA-S1 (Figure 24) and SA-S2 (Figure 25) in the fall. Spirogyra continued to dominate the algal assemblage at SA-S3 (Figure 26) in the fall. There was no clear dominant species at SA-S4 (Figure 27) in the fall.

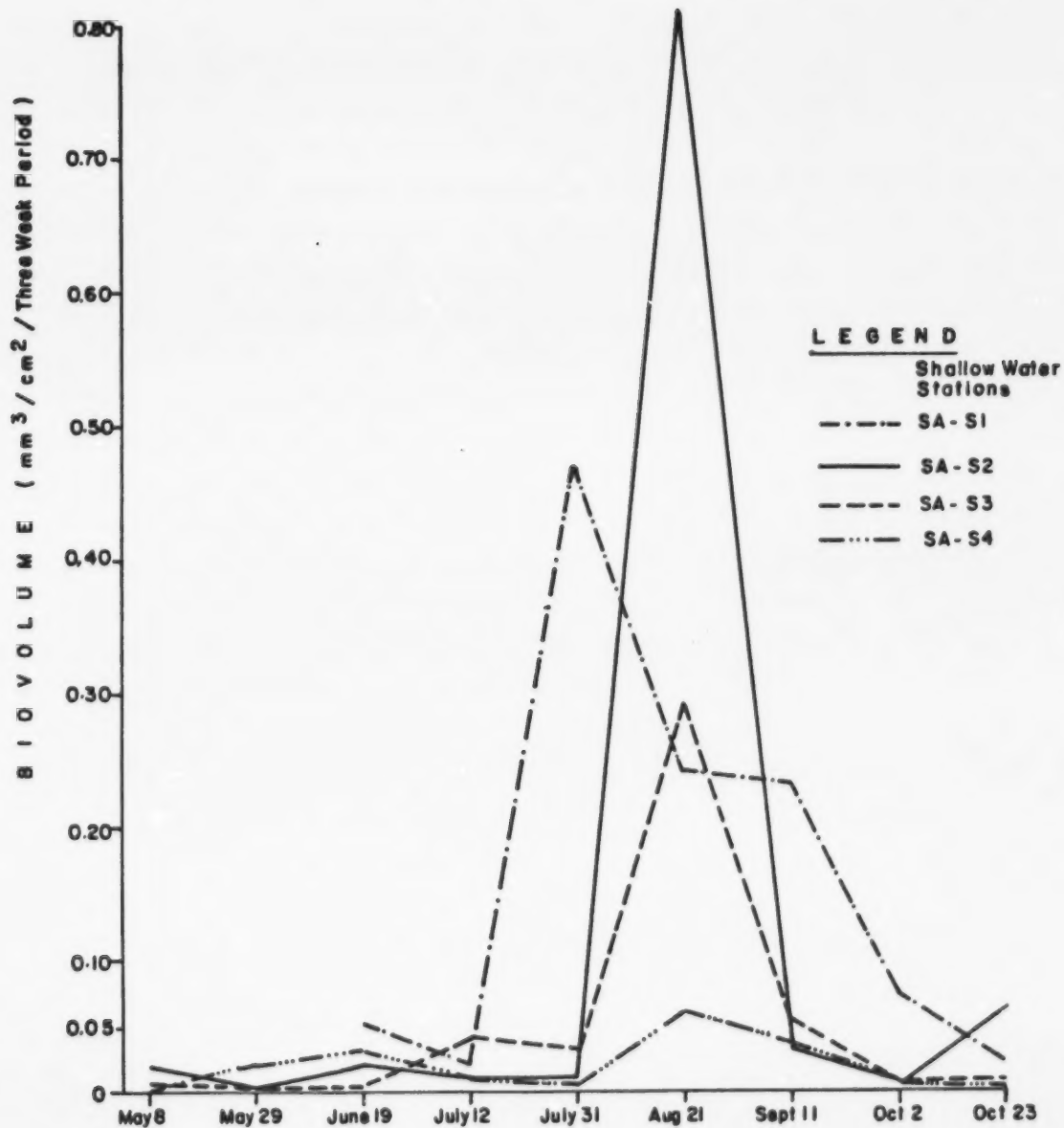


FIGURE 23 PERIPHYTON BIOVOLUME AT SHALLOW WATER STATIONS IN SHUSWAP LAKE DURING 1979

TABLE 17 PERIPHYTON BIOVOLUME ($\text{mm}^3/\text{cm}^2/\text{day}$) AT SHALLOW WATER STATIONS IN SHUSWAP LAKE DURING 1979

STATIONS	END OF APPROXIMATE THREE-WEEK PERIODS										Mean	S. Dev.
	May 8	May 29	June 19	July 12	July 31	Aug. 21	Sept. 11	Oct. 2	Oct. 23			
SA-S1	--	--	0.05	0.02	0.47	0.24	0.23	0.07	0.02		0.16	
SA-S2	0.02	0.003	0.02	0.01	0.009	0.81	0.03	0.003	0.06		0.11	
SA-S3	0.007	0.0006	0.005	0.005	0.03	0.29	0.05	0.007	0.004		0.05	
SA-S4	0.0006	0.02	0.03	0.03	0.002	0.06	0.03	0.007	0.0005		0.02	

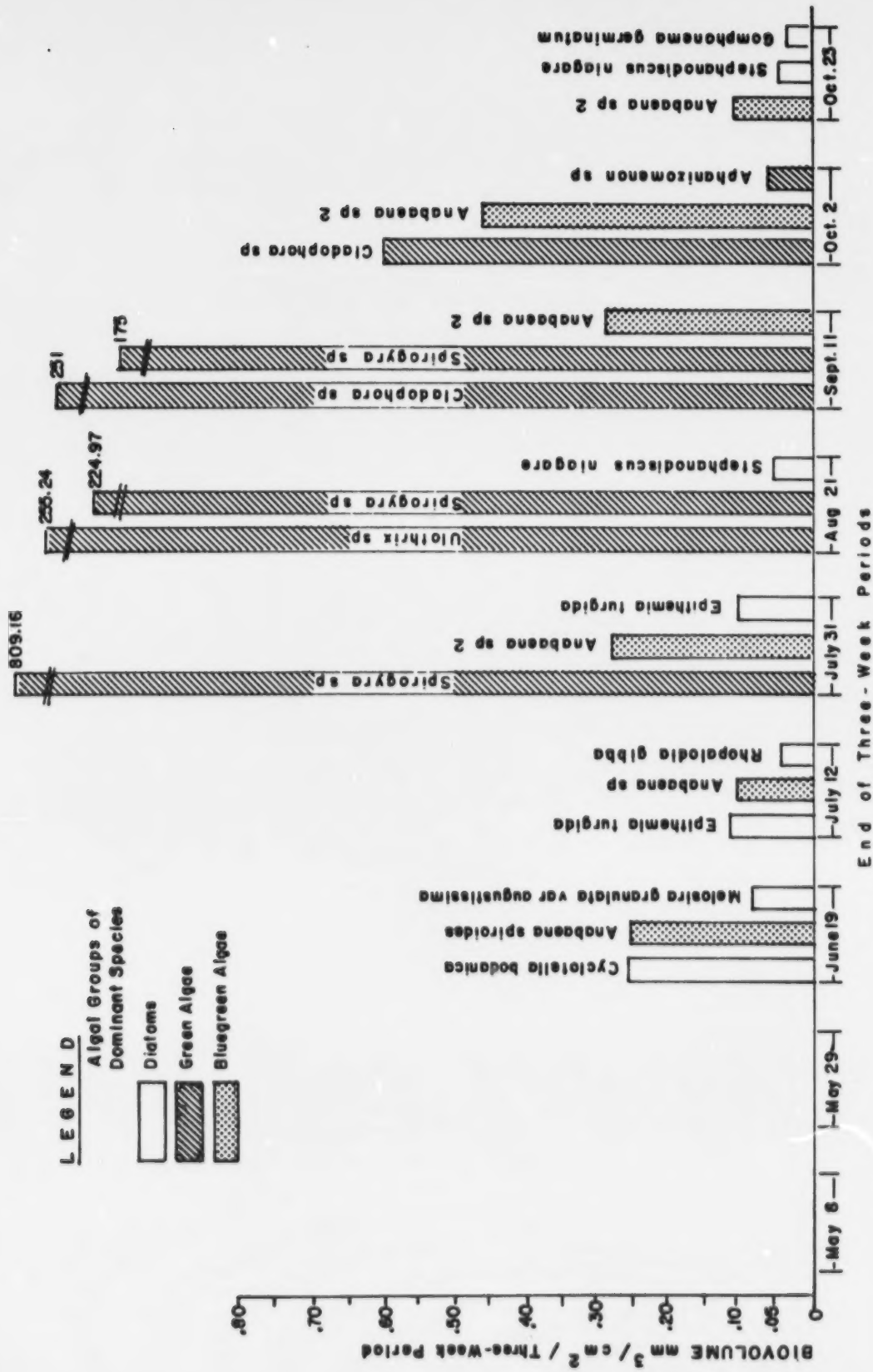


FIGURE 24 BIOVOLUME FOR THREE DOMINANT PERIPHYTON SPECIES AT STATION SA-SI IN 1979

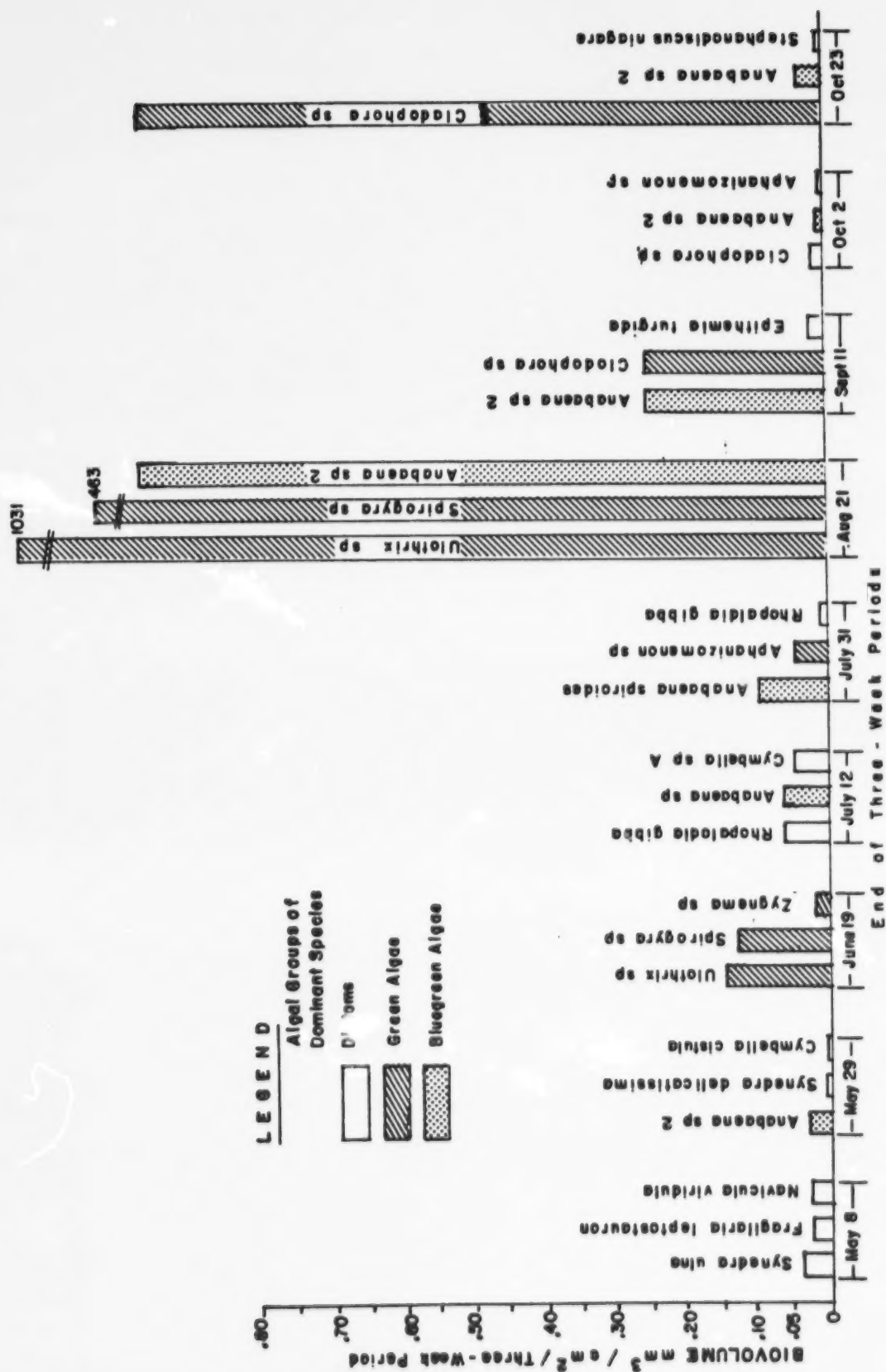


FIGURE 25 BIOVOLUME FOR THREE DOMINANT PERIPHYTON SPECIES AT STATION SA - S2 IN 1979

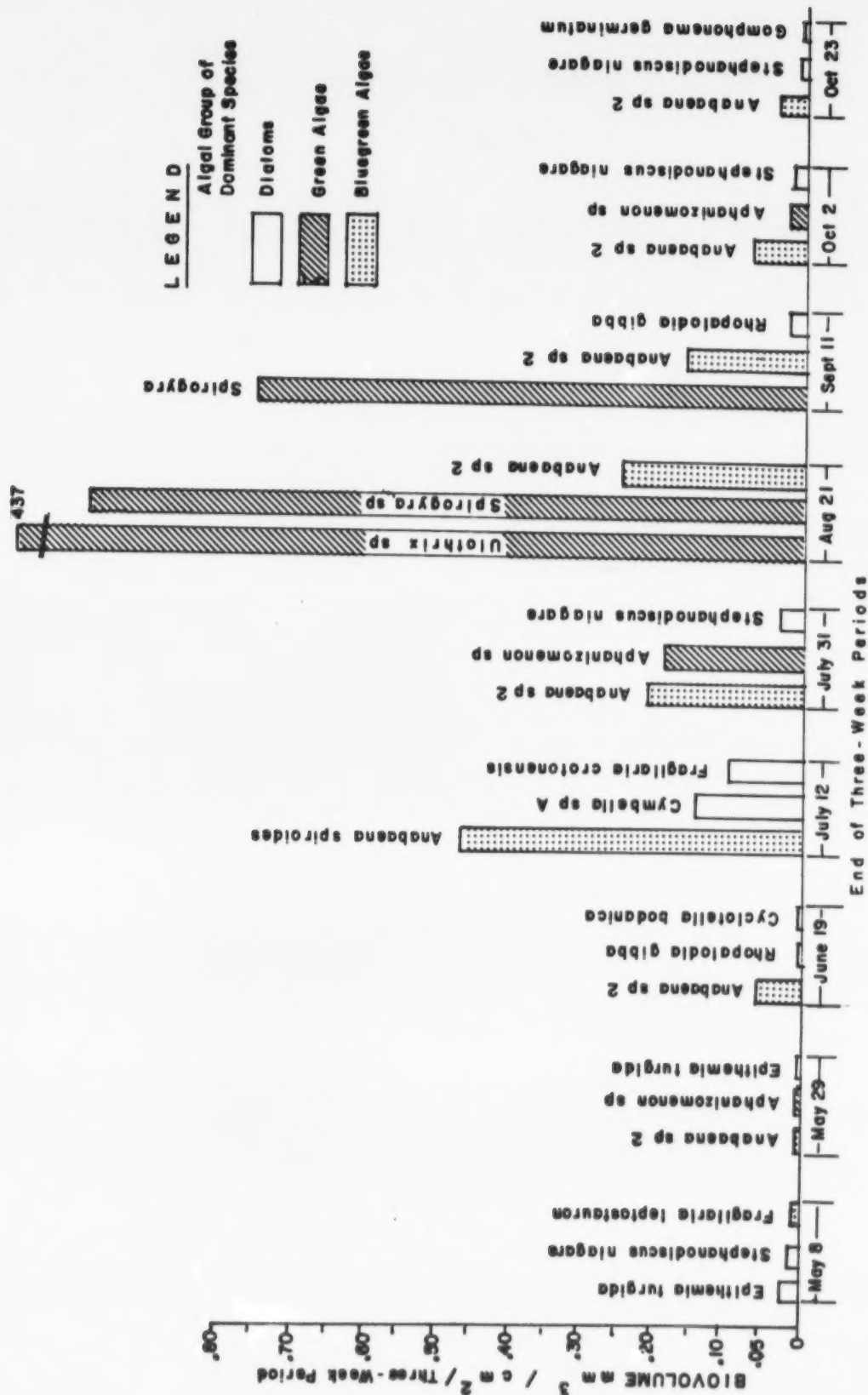


FIGURE 26 BIOVOLUME FOR THREE DOMINANT PERIPHYTON SPECIES AT STATION SA - S3 IN 1979

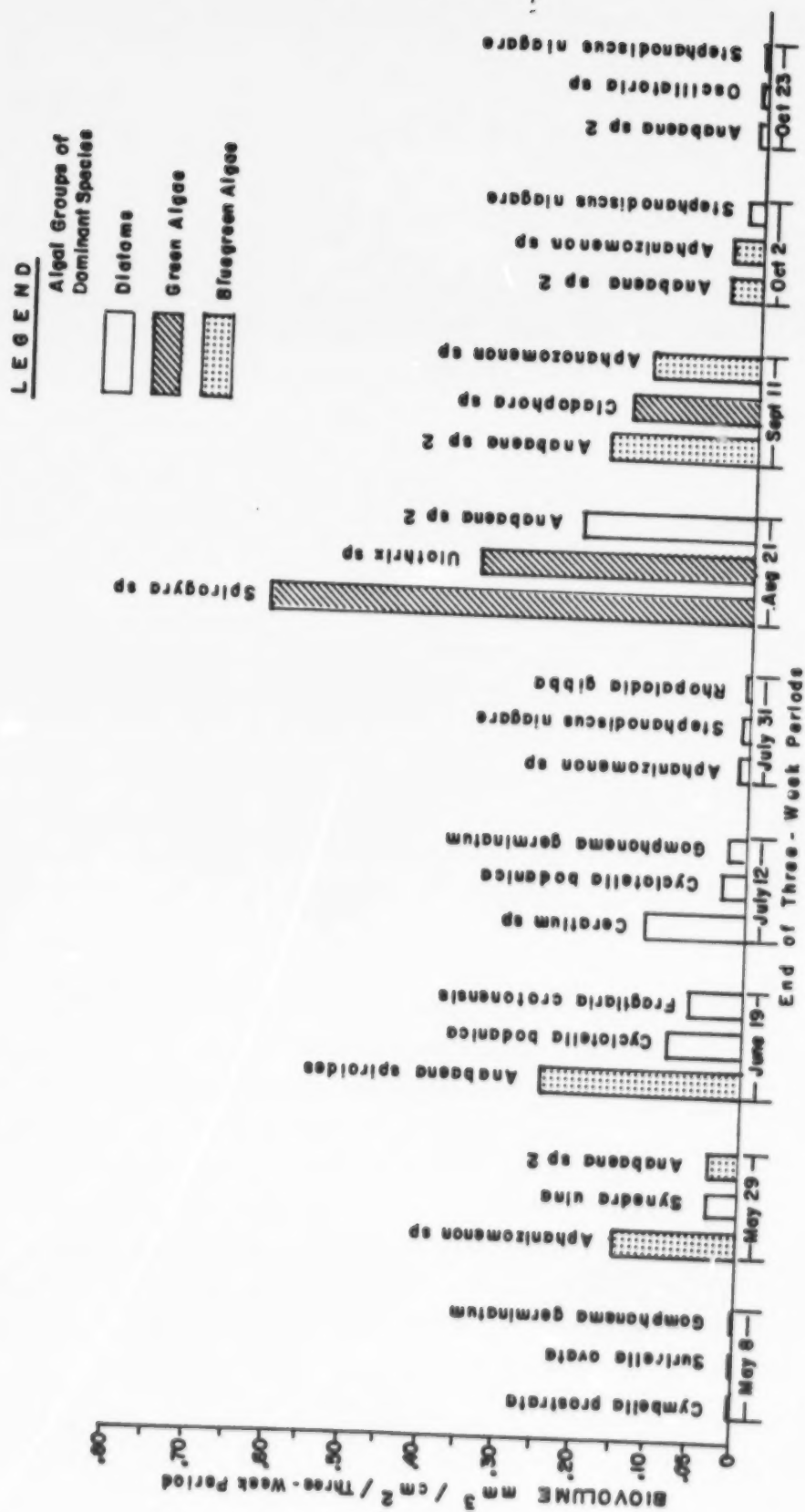


FIGURE 27 BIOVOLUME FOR THREE DOMINANT PERIPHYTON SPECIES AT STATION SA - S4 IN 1979

5.0 SUMMARY AND CONCLUSIONS

- 1) Eutrophication in Shuswap Lake was more advanced in Zone A (Tappen Bay area) than in Zone B (Salmon Arm) and C (Seymour Arm).

According to general ranges of various limnological characteristics such as total phosphorus, phytoplankton biovolume and dominant phytoplankton measured in 1978 and 1979, the trophic status of:

Zone A was mestrophic to eutrophic
Zone B was oligotrophic to meso-eutrophic
Zone C was ultra-oligotrophic to oligotrophic

- 2) The two major sources of phosphorus loading to Zone A were identified in 1978 as the Salmon Arm sewage treatment plant and the Salmon River.
- 3) The District of Salmon Arm's sewage treatment plant could be responsible for enhancing eutrophication in Zone A by supplying additional phosphorus to the system at critical times of the year (early-spring and late-summer) and thereby lengthening the phytoplankton growing season.

Generally, before spring freshet and after winter mixing, phosphorus levels are high and biovolume is low. However, both phosphorus levels and phytoplankton biovolume seemed unusually high in the spring at Stations 1 to 3 (Zone A). Approximately a week before peak flow from the Salmon River in April, 1979, these stations were weakly stratified and total dissolved phosphorus levels in the epilimnion were the highest recorded throughout the study. Correspondingly, the phytoplankton biovolume in April at Stations 1 to 3 was already as high as post-freshet (June 1979) biovolumes in Zone B. During April, before freshet, the sewage treatment plant contributed approximately 21% of the total dissolved

phosphorus loading to Zone A. This added phosphorus load from the STP may have been sufficient to allow algae to bloom sooner in Zone A than in Zone B or C. The latter zones received an allochthonous supply from the rivers alone. As expected, phytoplankton biovolumes in Zone B did not increase until after spring freshet (June 1979) when there was an increase in phosphorus loading from the rivers.

During the post-freshet flow period, the Salmon Arm sewage treatment plant contributed approximately 40% of the total phosphorus loading and 41% of the dissolved phosphorus loading to Zone A. Phytoplankton biovolume in Zone A was higher in August than in June 1979; whereas phytoplankton biovolume in Zone B was equivalent to the lower pre-freshet biovolumes. When the post-freshet algal population in Zone B appeared to have declined from lack of nutrients, the additional phosphorus loading to the lake from the sewage treatment plant may have been enough to allow phytoplankton in Zone A to continue to grow into the late summer.

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APPENDIX I

FISHERIES RESOURCES IN SHUSWAP LAKE

- (a) Commercial Salmon Species Found in the Shuswap Lake System
- (b) Estimates of Annual Salmon Escapements By Species to the Shuswap Lake System

APPENDIX Ia COMMERCIAL SALMON SPECIES FOUND IN THE SHUSWAP LAKE SYSTEM

Sockeye - The area is known primarily for its large sockeye runs. The majority of the sockeye spawn in the Adams and Little Rivers with smaller runs spawning in the Seymour, Lower Shuswap and Eagle Rivers. Sockeye populations in this system exhibit cyclic dominance (4 years) which causes wide variations in spawning populations.

Chinook - Chinook salmon spawn in most streams tributary to the Shuswap Lake system with major runs occurring in the Lower Shuswap and Adams Rivers.

Coho - Coho salmon spawn in the most streams tributary to the Shuswap Lake system with major runs occurring in the Upper Adams, Bessette and Eagle Rivers.

Pink - Pink Salmon only occasionally in the Shuswap Lake system.

*Taken from Graham and Russell, 1979

APPENDIX 1b ESTIMATES OF ANNUAL SALMON ESCAPEMENTS BY SPECIES TO THE SHUSWAP LAKE SYSTEM (GRAHAM & RUSSEL, 1979)

SPECIES	NAME OF STREAM	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Sockeye	Adams River	3,983	45,908	1,315,000	280,000	4,325	40,546	1,000,000	30,000	5,100	1,500
	Upper Adams R.	0	0	25	0	25	0	25	25	25	0
	Anstey River	0	0	500	50	0	0	1,500	25	0	NR
	Eagle River	0	75	7,525	200	25	50	3,700	200	0	444
	Little River	0	6,775	222,400	12,500	75	1,500	100,000	15,000	175	8,000
	Momich River	617	0	200	25	750	0	25	0	3,000	30
	Scotch Creek	126	3,395	6,300	750	0	7,500	3,900	25	38	13,636
	Seymour River	3,879	7,327	14,275	15,000	3,500	3,500	35,000	30,000	8,500	6,018
	Lower Shuswap R.	25	1,500	29,000	7,500	200	7,452	75,000	15,000	82	7,500
	Middle Shuswap R.	0	0	4,559	206	0	0	3,500	25	0	32
	Sirmax River	0	50	200	3	25	69	200	0	25	70
	Adams River	3,500	5,000	1,500	750	1,900	16,500	1,500	1,500	400	1,700
	Upper Adams R.	0	0	0	0	0	0	150	0	0	0
	Bessette R.	0	0	25	25	25	0	25	25	0	15
Chinook	Eagle River	200	400	300	740	300	350	400	400	0	756
	Little River	400	200	750	200	200	200	300	400	100	600
	Salmon River	275	200	200	400	0	0	200	150	50	320
	Scotch Creek	25	0	0	0	0	0	0	0	0	0
	Seymour River	0	25	0	0	0	0	0	0	0	25
	Lower Shuswap R.	7,500	7,500	7,500	7,500	4,500	9,000	10,000	15,000	2,500	9,500
	Middle Shuswap R.	400	500	750	750	300	400	750	750	400	550
	Adams River	400	750	400	300	200	300	150	200	10	338
	Upper Adams R.	NR	P	P	P	P	P	150	75	NR	150
	Anstey River	25	25	25	0	25	25	25	25	25	NR
	Bessette River	1,500	1,500	750	750	2,000	750	1,500	750	25	70
	Eagle River	1,500	750	1,500	1,500	1,200	1,800	3,500	1,500	1,100	2,694
	Tappen Creek	25	25	25	25	25	25	0	25	1	12
	Momich River	75	200	NR	75	25	25	25	25	0	20
Coho	Salmon River	1,250	1,500	750	1,500	2,000	400	1,500	750	900	1,580
	Scotch Creek	25	0	200	25	25	25	25	25	5	0
	Seymour River	0	NR	NR	NR	NR	NR	NR	2	1	25
	Lower Shuswap R.	400	750	400	75	300	250	100	200	40	100
	Middle Shuswap R.	400	750	400	400	400	500	500	200	60	594
	Sirmax River	400	200	200	213	104	165	200	75	25	40

P - Present
NR - None Recorded

APPENDIX II

SUMMARY TABLES OF PHYSICAL AND CHEMICAL DATA FROM ZONES A, B, AND C

- (a) Temperature Readings
- (b) Secchi Readings/Photic Zones
- (c) Turbidity Readings
- (d) Conductivity Readings
- (e) Total Phosphorus Concentrations
- (f) Total Dissolved Phosphorus Concentrations
- (g) Nitrate/Nitrite Concentrations
- (h) Ammonia Concentrations
- (i) Total Dissolved Nitrogen Concentrations
- (j) Particulate Nitrogen Concentrations
- (k) Total Nitrogen Concentrations
- (l) Particulate Carbon Concentrations
- (m) Silicon Dioxide Concentrations

APPENDIX II(a) TEMPERATURE (°C) READINGS FROM SHUSHAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION	JUNE			SEPTEMBER			STATION			NOVEMBER		
	Range	Mean	S. Dev.**	Range	Mean	S. Dev.	Range	Mean	S. Dev.	Range	Mean	S. Dev.
A 1-11	EPI* 10.0-18.0	14.86	3.38	16.7-17.5	17.04	0.39						
	HYP 3.9-11.0	6.31	2.34	4.0-9.3	5.31	1.40						
B 12-17,							1-11	ISO		3.0-6.4	5.52	0.70
21-30	EPI 9.3-17.5	14.29	2.48	15.0-18.2	16.46	0.73						
	HYP 3.6-8.2	4.34	0.88	3.5-5.3	4.24	0.44						
C 31-33	EPI 13.5-15.0	14.57	0.68	15.9-16.2	16.10	0.14	13,16	ISO		4.8-5.5	5.13	0.27
	HYP 4.0-4.6	4.31	0.26	3.7-4.4	4.05	0.31				-	-	-

1979

ZONE & STATION	APRIL			STATION			JUNE			AUGUST			OCTOBER		
	Range	Mean	S. Dev.	Range	Mean	S. Dev.	Range	Mean	S. Dev.	Range	Mean	S. Dev.	Range	Mean	S. Dev.
A 1-3	EPI 3.7-6.0	4.78	0.88	1-11	EP		7.0-20.0	14.91	3.78	18.6-25.5	22.51	2.21	11.9-13.0	12.58	0.31
	HYP 3.0-4.2	3.47	0.46		HYP		3.5-12.5	5.41	1.82	4.4-14.2	6.76	2.14	3.9-7.0	5.17	0.77
4-11	ISO 3.0-4.5	3.93	0.44												
B				16	EPI		9.8-20.5	15.15	7.57	21.5-24.5	23.0	2.12	12.3-12.5	12.4	0.14
					HYP		5.5-5.6	5.55	0.07	4.1-4.3	4.2	0.14	3.5-3.7	3.6	0.14
16	ISO 4.2-4.5	4.4	0.14												

*EPI = epilimnion

HYP = hypolimnion

ISO = isothermal

**S. Dev. = standard deviation

APPENDIX II(b) SECCHI READINGS/PHOTIC ZONES (metres) FOR SHUSAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION		JUNE				SEPTEMBER				NOVEMBER				
		Range		Mean	S.Dev.	Range		Mean	S. Dev.	Range		Mean	S. Dev.	
		n				n				n				
A	1-11	secchi	11	1.5-2.5	2.33	0.33	11	2.3-4.0	3.34	0.42	11	32.5-5.25	4.61	0.76
		photic	11	3.75-6.25	5.57	0.82	11	6.25-10.00	8.35	1.04	11	8.13-13.13	11.52	1.90
B	12-17, 21-30	secchi	16	2.5-5.0	3.69	0.84	16	3.75-8.25	5.20	1.36	2	5.75-8.0	6.88	1.12
		photic	16	6.25-12.5	9.22	2.11	16	9.38-20.63	13.09	3.4	2	14.8-20.0	17.19	2.81
C	31-33	secchi	3	5.0-5.5	5.33	0.24	3	7.0-7.5	7.28	0.21				
		photic	3	12.5-13.75	13.33	0.59	3	17.5-18.75	17.21	0.52				

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1979

ZONE & STATION		APRIL			STATION			JUNE			AUGUST			OCTOBER					
		n	Range	Mean	S. Dev.	n	Range	Mean	S.Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.		
A	1-3	secchi	3	2.25-3.75	3.25	0.71	1-11	7	2.0-3.5	2.78	0.59	10	2.5-3.5	3.05	0.42	11	4.0-6.0	4.73	0.62
	4-11	"	8	4.75-6.25	5.44	0.56													
	1-3	photic	3	5.63-9.38	8.13	1.77	1-11	7	5.0-8.75	6.96	1.47	10	6.25-8.75	7.63	1.04	11	10.0-15.0	11.82	1.54
	4-11	"	8	11.88-15.03	13.59	1.39													
B	16	secchi		-	9.75		16	1	-	4.0	-	1	-	4.0	-	1	-	7.0	-
	16	photic		-	24.38		16	1	-	10.0	-	1	-	10.0	-	1	-	17.5	-

S. Dev. = standard deviation
photic = 2.5 x secchi

APPENDIX II(c)
TURBIDITY READINGS (Formazin Turbidity Units) FOR SHUSHAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION		JUNE				SEPTEMBER				STATION		NOVEMBER				
		Range		Mean	S.Dev.**	Range		Mean	S.Dev.	n	Range	Mean	S.Dev.			
		n				n										
A	1-11	EPI*	13	1-2.3	1.45	0.32	22	0.48-1.8	1.00	0.30	1-11	ISO	44	-	0.96	0.36
		HWP	13	0.46-2.3	1.20	0.43	18	0.40-1.1	0.83	0.21						
B	12-17, 21-30	EPI	32	0.4-3.0	1.05	0.48	32	0.36-1.0	0.66	0.19	13,16	ISO	8	0.44-0.84	0.74	0.17
		HWP	32	0.18-3.3	0.75	0.66	32	0.34-1.0	0.54	0.19						
C	31-33	EPI	6	0.21-1.0	0.62	0.29	6	0.48-0.78	0.59	0.10						
		HWP	6	0.25-0.65	0.36	0.16	6	0.36-0.65	0.52	0.11						

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1979

[illegible]

EPI = epilimnion; ISO = isothermal

HYP = hypolimnion
**S. Dev. = standard deviation

NOTE: If a value was recorded as being less than the detection limit (1.0 FTU), half the detection limit (0.5 FTU) was used for that value when calculating means

APPENDIX II(e)
TOTAL PHOSPHORUS CONCENTRATIONS (ug/l) IN SHUSHAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION		JUNE				SEPTEMBER				STATION		NOVEMBER					
		n		Range		Mean		S.Dev.**		n		Range		Mean		S.Dev.	
A	1-11	EPI*	18	4-46	16	9	22	9-15	11	1	1-11	43	5-17	10	2		
		HYP	19	4-25	12	5	18	5-18	9	4							
B	12-17,										13,16	8	3-6	5	1		
	21-30	EPI	32	5-14	8	2	30	4-15	8	2							
		HYP	32	3-10	5	2	32	3-43	7	7							
C	31-33	EPI	6	4-6	5	1	6	3-7	5	1							
		HYP	6	2-3	3	0.4	6	3-8	4	2							

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1979

ZONE & STATION		APRIL			STATION	JUNE			AUGUST			OCTOBER							
		n	Range	Mean		S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.					
A	1-3 EPI	6	7.8-21.3	11.3	4.6	1-11	EPI	22	3.5-56.5	14.0	11.0	22	5.0-14.0	11	12	22	5.5-8.9	7	1
	1-3 HYP	6	20.8-40.3	30.1	7.1		HYP	22	2.0-21.1	8.0	5.0	22	5.0-20.9	9	4	19	3.3-28.6	10	7
	4-44 ISO	32	5.0-19.8	8.4	2.8														
B						16	EPI	2	3.5-5.0	4.0	1.0	2	8.5-11.0	10	2	2	4.8-5.5	5	0
	16 ISO	4	3.1-7.8	5.0	2.0	16	HYP	2	2.0-3.0	3.0	1.0	2	5.0	5	0	2	3.3-4.0	4	0

*EPI = epifimion

EPI = epilimnion
HYP = hypolimnion
ISO = isothermal

1978

ZONE & STATION		JUNE				SEPTEMBER				STATION		NOVEMBER			
		n	Range	Mean	S.Dev.**	n	Range	Mean	S. Dev.		n	Range	Mean	S. Dev.	
A	1-11	EPI*	19	4-8	5.7	1.2	22	3-8	4.4	1.0	1-11	44	2-85	5.1	1.6
		HYP	19	4-14	6.9	2.8	17	3-16	6.2	3.4					
B	12-17,										13,16	7	< 2-7	2.3	0.7
	21-30	EPI	32	2-7.5	3.3	1.0	32	2-5	3.5	0.8					
		HYP	32	2-4	3.0	0.7	30	2-15	3.3	2.5					
C	31-33	EPI	6	2-3	2.4	0.5	6	< 2-4	2.5	0.8					
		HYP	6	1-2	1.7	0.5	5	< 2-4.5	2.1	1.6					

1979

ZONE & STATION		APRIL			STATION	JUNE			AUGUST			OCTOBER								
		n	Range	Mean S. Dev.		n	Range	Mean S. Dev.	n	Range	Mean S. Dev.	n	Range	Mean S. Dev.						
A	1-3	EPI	6	5.0-12.5	6.3	2.8	1-11	EPI	22	< 2-16.8	5.3	4.5	22	2.5-6.5	3.8	1.1	22	2.0-6.7	3.6	1.5
		HYP	6	5.0-18.0	13.4	4.5		HYP	21	< 2-14.0	5.0	3.4	22	2.0-12.5	4.6	2.5	19	2.0-17.8	6.3	4.1
	4-11	ISO	32	2.0-8.0	2.9	1.6														
B							16	EPI	1	-	< 2	-	2	3.5-4.0	3.8	0.4	2	2.0-4.8	3.4	2.0
							16	HYP	2	-	< 2	-	2	3.5-4.0	3.8	0.4	1	0	2.0	0
	16	ISO	4	< 2.0-2.0	1.3	0.5														

*EPI = epilimnion

HYP = hypolimnion

ISO = isothermal

**S. Dev. = standard deviation

Note: If a value was recorded as being less than the detection limit (< 2.0 ug/l) half the detection limit (1.0 ug/l) was used for that value when calculating means.

APPENDIX III(1) TOTAL DISSOLVED NITROGEN CONCENTRATIONS (ug/l) IN SALEMAR LAKE DURING 1978 AND 1979

1978

ZONE & STATION	JUNE			SEPTEMBER			STATION			NOVEMBER		
	n	Range	Mean	S.Dev.**	n	Range	Mean	S.Dev.	n	Range	Mean	S.Dev.
A 1-11 EPI*	19	110-200	156.6	25.5	22	87-140	106.0	11.8				
HYP	19	130-220	158.9	25.6	18	100-240	166.4	32.8				
B 12-17,									1-11	ISO	44	110-150 125.3 9.7
21-30 EPI	32	82-130	109.4	14.3	32	10-180	88.6	34.8				
HYP	32	96-170	137.2	20.2	32	100-190	145.8	16.8				
C 31-33 EPI	6	100-120	108.3	9.8	6	60-89	72.5	12.5	13,16	ISO	8	120-140 123.8 7.4
HYP	6	130-140	138.3	4.1	6	70-140	118.3	24.8				

1979

ZONE & STATION		APRIL			STATION	JUNE			AUGUST			OCTOBER								
		n	Range	Mean S. Dev.		n	Range	Mean S. Dev.	n	Range	Mean S. Dev.	n	Range	Mean S. Dev.						
A	1-3	EPI	6	120-170	136.7	16.0	1-11	EPI	22	95-220	131.9	32.6	22	135-205	156.6	19.7	22	100-182.5	116.6	19.8
		HYP	6	20-28	261.7	27.9		HYP	22	105-240	151.8	28.4	22	90-225	166.1	28.4	19	170-750	230.5	129.3
	4-11	ISO	32	13-21	145.9	19.5														
B							16	EPI	2	-	130.0	0	2	-	145.0	0	2	95-105	100.0	7.1
							16	HYP	2	140-145	142.5	3.5	2	-	155.0	0	2	-	175.0	0
	16	ISO	4	-	140.0	0														

EPI = epilimnion

HYP = hypolimnion

ISO = isothermal

**S.Dev. = standard deviation

Note: Total dissolved nitrogen values may be slight overestimates of the actual lake levels because the samples were allowed to settle and then the decant was used for the analysis.

APPENDIX II(J) PARTICULATE NITROGEN CONCENTRATIONS (ug/l) IN SHUSHAP LAKE DURING 1978 AND 1979

1978

ZONE & STATION	JUNE				SEPTEMBER				NOVEMBER			
	STATION		JUNE		SEPTEMBER		SEPTEMBER		NOVEMBER		NOVEMBER	
	n	Range	Mean	S.Dev.**	n	Range	Mean	S.Dev.	n	Range	Mean	S.Dev.
A 1-11	EPI*	19	9-950	59.4	21.8	22	27-58	41.6	8.0			
	HYP	19	< 5-560	19.5	14.1	18	< 5-28	8.9	5.7			
B 12-17, 21-30										1-11	ISO	44
											10-52	20.8
												6.9
C 31-33										13,16	ISO	8
											< 10-17	12.3
												4.7

1979

ZONE & STATION	APRIL				JUNE				AUGUST				OCTOBER							
	STATION		APRIL		JUNE		JUNE		AUGUST		AUGUST		OCTOBER							
	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.				
A	1-3	EPI	6	31-106	54.3	25.6	1-11	EPI	22	< 5-125	47.0	32.8	22	< 5-101	56.2	28.5	22	25-39	32.7	3.7
		HYP	6	15-67	30.2	17.3		HYP	22	< 5-35	4.0	6.9	22	< 5-93	16.2	27.5	19	< 5-30	8.7	8.6
	4-11	ISO	32	12-56	35.9	10.9														
B							16	EPI	2	11-67	39.0	39.6	2	55-64	59.5	6.4	2	28-31	29.5	2.1
							16	HYP	2	< 5	< 5	0	2	< 5	< 5.0	0	2	< 5	< 5.0	0
	16	ISO	4	13-18	15.5	2.1														

*EPI = epilimnion
HYP = hypolimnion
ISO = isothermal
**S. Dev. = standard deviation

Note: Half the detection limit (2.5 ug/l) was used for values less than the detection limit (2.0 ug/l) when calculating means.

APPENDIX II(1)

1978

ZONE & STATION		JUNE				SEPTEMBER				NOVEMBER						
		STATION		SEPTEMBER		NOVEMBER		STATION		SEPTEMBER		NOVEMBER				
		n	Range	Mean	S.Dev.**	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.			
A	1-11	EPI*	19	150-606	449.1	128.6	22	240-650	345.0	92.0						
		HMP	19	100-410	207.7	85.0	18	39-210	124.3	54.3						
B	12-17, 21-30	EPI	32	170-440	277.8	78.3	32	95-350	217.7	66.7	1-11	150	44	120-250	181.8	34.5
		HMP	32	39-400	150.3	90.1	32	< 10-210	77.4	40.8						
C	31-33	EPI	6	210-260	235.0	17.6	6	95-140	110.6	15.6	13,16	150	8	110-200	145.0	27.8
		HMP	6	82-110	92.2	10.2	6	40-140	64.0	37.5						

1979

ZONE & STATION		APRIL			JUNE			AUGUST			OCTOBER		
		n	Range	S. Dev.	n	Range	S. Dev.	n	Range	S. Dev.	n	Range	S. Dev.
A	1-3 EPI	6	236-646	374.7	141.4								
	HYP	6	192-710	309.8	199.4								
	4-11 ISO	32	135-1360	289.9	196.9								
B													
	16 ISO	4	135-163	150.0	13.6								

APPENDIX II(m) SILICON DIOXIDE CONCENTRATIONS (mg/l) IN SHUSHAP LAKE DURING 1978 AND 1979

1978

JUNE & STATION	JUNE				SEPTEMBER				NOVEMBER			
	n	Range	Mean	S.Dev.**	n	Range	Mean	S.Dev.	n	Range	Mean	S.Dev.
A 1-11 EPI*	19	6.3-8.5	7.0	0.6	22	5.6-6.3	5.8	0.2				
HYP	19	6.6-8.5	7.4	0.5	18	5.6-8.3	7.1	0.6	1-11 ISO	44	6.4-7.5	6.6 0.3
B 12-17, 21-30 EPI	32	6.0-7.6	6.3	0.4	32	5.1-5.9	5.4	0.2				
HYP	32	6.2-7.1	6.5	0.2	32	5.4-7.9	6.5	0.5	13,16 ISO	8	6.4-6.7	6.5 0.1
C 31-33 EPI	6	5.4-5.9	5.7	0.2	6	4.5-5.8	5.1	0.6				
HYP	6	5.8-6.0	5.9	0.1	6	5.7-5.9	5.8	0.1				

1979

ZONE & STATION		APRIL				STATION		JUNE				AUGUST				OCTOBER			
		n	Range	Mean	S. Dev.			n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.	n	Range	Mean	S. Dev.
A	1-3 EPI	6	6.57-6.95	6.73	0.11	1-11	EPI	22	4.30-6.97	5.69	0.66	22	4.04-4.54	4.24	0.15	22	4.7107.70	5.24	0.54
	HYP	6	10.40-11.66	11.08	0.39		HYP	22	5.93-8.19	6.95	0.51	22	4.09-7.92	6.82	0.77	19	6.42-8.30	7.04	0.29
	4-11 ISO	32	6.50-8.28	6.59	1.22														
B					16	EPI	2	4.60-6.33	5.48	1.22	2	2.97-4.06	3.53	0.77	2	4.71	4.71	0	
	16 ISO	4	6.72-6.85	6.77	0.05	16	HYP	2	6.50-6.85	6.67	0.24	2	6.31-6.72	6.52	0.28	2	6.42-6.74	6.58	0.11

*EPI = epilimnion
HYP = hypolimnion
ISO = isothermal

**S. Dev. = standard deviation

APPENDIX III

PHYSICAL AND CHEMICAL DATA
FROM SHALLOW WATER STATIONS

- (a) Surface Temperatures
- (b) Turbidity
- (c) pH
- (d) Conductivity
- (e) Phosphorus
- (f) Nitrogen
- (g) Silicon Dioxide

APPENDIX III(a) SURFACE TEMPERATURES AT SHALLOW WATER STATIONS (°C) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	16.0	19.0	19.0	-	25.0	21.0	15.5	12.0
SA-S2	10.5	12.0	16.0	19.0	19.0	-	25.0	20.5	17.0	13.0
SA-S3	11.0	11.0	16.0	19.0	19.0	-	25.0	20.5	16.5	13.0
SA-S4	4.5	8.0	11.5	19.0	20.5	-	24.0	19.0	17.0	13.0

APPENDIX III(b)

TURBIDITY OF SHALLOW WATER STATIONS (Formazin Turbidity Units) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	3.2	2.8	3.8	5.3	3.1	2.2	1.4	1.7
SA-S2	1.2	2.5	1.7	3.3	1.3	2.6	1.6	1.5	1.4	1.2
SA-S3	1.3	3.4	2.0	2.2	1.8	2.9	2.0	1.2	1.3	1.2
SA-S4	< 1.0	1.3	< 1.0	1.6	1.8	1.3	1.1	< 1.0	1.0	< 1.0

APPENDIX III(c) PH OF SHALLOW WATER STATIONS 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	8.0	8.0	7.6	7.9	8.2	8.0	7.9	7.8
SA-S2	8.0	8.1	8.0	8.1	7.9	8.0	8.3	7.9	7.9	7.9
SA-S3	8.0	8.1	8.1	8.0	7.6	8.0	8.3	8.0	7.9	7.9
SA-S4	8.0	8.0	7.9	8.1	7.8	7.8	7.9	7.8	7.9	7.8

APPENDIX III(d) CONDUCTIVITY OF SHALLOW WATER STATIONS (umhos/cm) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	131	125	143	149	120	110	114	118
SA-S2	118	119	121	124	111	115	110	110	111	112
SA-S3	118	117	123	125	113	114	109	108	109	112
SA-S4	110	108	111	115	109	108	104	102	98	104

APPENDIX III(e) PHOSPHORUS FOR SHALLOW WATER STATIONS (ug/l) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
<u>Total Phosphorus</u>										
SA-S1	--	--	21.0	26.0	33.9	52.7	30.9	14.9	8.2	10.5
SA-S2	12.7	143.0	27.3	26.0	14.0	14.8	13.5	13.4	7.5	8.2
SA-S3	19.1	--	15.0	23.0	11.5	15.0	14.0	10.3	6.5	8.3
SA-S4	4.3	6.0	7.3	14.3	12.0	94.0	9.9	8.6	3.0	5.8
<u>Total Dissolved Phosphorus</u>										
SA-S1	--	--	8.0	10.5	13.2	13.7	5.5	4.1	< 2	15.0*
SA-S2	3.3	< 2	3.4	11.0	6.0	7.4	4.0	5.2	< 2	6.0
SA-S3	2.5	< 2	4.3	18.0	10.8	5.8	5.0	4.5	< 2	4.4
SA-S4	2.5	< 2	3.3	7.0	3.5	5.5	4.0	3.8	< 2	3.7
<u>Total Particulate Phosphorus</u>										
SA-S1	--	--	13.0	15.5	20.7	39.0	25.4	10.8	< 8.2	--
SA-S2	9.4	141.0	23.9	15.0	8.0	7.4	9.5	8.2	< 7.5	2.2
SA-S3	16.6	--	10.7	5.0	0.7	9.2	9.0	5.8	< 6.5	3.9
SA-S4	1.8	< 4	4.0	7.3	8.5	88.5	5.9	4.8	< 3.0	2.1

Dissolved higher than total

APPENDIX III(f)

NITROGEN FOR SHALLOW WATER STATIONS (ug/l) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	2.8	< 2.0	< 5.0	< 2.0	< 2.0	< 2.0	< 2.0	2.9
SA-S2	30.0	226.0	< 2.0	< 2.0	< 5.0	< 2.0	< 2.0	< 2.0	< 2.0	2.5
SA-S3	32.5	< 10.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	< 2.0	2.0
SA-S4	73.8	42.0	25.9	< 2.0	< 5.0	< 2.0	< 2.0	< 2.0	< 2.0	2.0
<u>Nitrate/Nitrite</u>										
SA-S1	--	--	3.5	< 2.0	2.5	< 2.0	< 2.0	2.0	4.5	10.0
SA-S2	< 2.0	3.8	8.0	< 2.0	2.0	< 2.0	< 2.0	2.0	4.7	5.5
SA-S3	2.5	< 2.0	2.0	< 2.0	2.7	< 2.0	2.2	2.5	3.8	4.4
SA-S4	< 2.0	2.0	7.5	< 2.0	2.0	5.5	4.5	< 2.0	5.2	2.0
<u>Ammonia</u>										
<u>Total Dissolved Nitrogen</u>										
SA-S1	--	--	175	193	160	205	210	150	175	120
SA-S2	120	120	145	155	130	200	180	145	170	105
SA-S3	130	120	145	148	135	205	175	145	165	125
SA-S4	140	130	150	150	125	175	130	130	150	100

*Dissolved higher than total

APPENDIX III(g) SILICON DIOXIDE FOR SHALLOW WATER STATIONS (mg/l) 1979

STATION	APRIL 23	MAY 8	MAY 29	JUNE 19	JULY 12	JULY 31	AUG. 21	SEPT. 11	OCT. 2	OCT. 23
SA-S1	--	--	9.3	6.4	5.8	5.9	4.7	4.4	4.6	5.0
SA-S2	6.5	6.2	6.5	6.4	3.8	4.3	4.2	4.4	4.5	4.7
SA-S3	6.5	6.2	6.9	6.5	3.8	4.3	4.1	4.4	4.4	4.7
SA-S4	6.7	6.5	5.9	5.4	3.6	4.3	4.2	4.4	4.4	4.6

APPENDIX IV

PHYTOPLANKTON DATA - DOMINANT ALGAE IN ZONE A, B AND C

APPENDIX IV(a)

TABLE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($\text{cm}^3/\text{m}^3 \times 0.001$) JUNE 1978

	STATIONS											MEAN
	1	2	3	4	5	6	7	8	9	10	11	SUM
<i>Agallaria crotonensis</i>	2114.59	1991.46	1498.95	1359.76	1426.68	2355.50	1084.06	1929.90	990.38	824.42	1905.81	17481.51
<i>Arctium sp.</i>	1610.85	--	--	805.42	--	--	--	--	--	805.42	--	3221.69
<i>Chlorella spiroides</i>	1421.67	458.09	379.11	600.25	521.28	663.45	631.85	252.74	537.07	1942.94	552.87	7961.32
<i>Chlorella fenestrata</i>	438.26	287.50	140.24	220.88	427.74	217.38	213.87	269.97	108.69	77.13	140.24	2541.90
<i>Coscinella granulata</i> var <i>augustissima</i>	409.35	312.76	335.76	296.66	170.18	248.37	257.57	114.98	170.18	232.97	96.59	2665.37
<i>Cryptomonas borealis</i>	171.01	142.51	99.75	178.13	156.76	142.51	142.51	149.63	142.51	114.00	135.38	1574.70
<i>Hydrodictyon ulna</i>	152.69	61.07	30.54	--	--	--	30.54	--	--	--	--	274.84
<i>Phaeodiscus niagarae</i>	106.47	--	--	106.47	--	--	--	--	--	106.47	--	319.41
<i>Agallaria capucina</i>	--	3847.66	--	--	--	--	--	--	--	--	--	3847.66
<i>Chlorella herculeanum</i>	--	139.04	--	--	--	139.04	--	--	--	--	--	278.08
<i>Chlorella sp.</i>	--	--	30.91	--	129.84	197.85	--	--	--	--	--	358.60
<i>Chlorella sp.</i>	--	--	26.99	--	--	--	--	--	--	--	--	26.99
<i>Chlorella sp.</i>	--	--	--	128.48	--	--	--	--	--	--	--	128.48
<i>Chlorella sp.</i>	--	--	--	--	49.54	--	--	--	--	--	--	49.54
<i>Chlorella sp.</i>	--	--	--	--	38.00	--	--	--	--	--	25.11	63.11
<i>Chlorella sp.</i>	--	--	--	--	--	150.95	--	--	--	--	--	150.95
<i>Chlorella sp.</i>	--	--	--	--	--	--	37.93	--	37.93	75.85	--	151.71
<i>Chlorella sp.</i>	--	--	--	--	--	--	35.59	--	--	--	38.00	73.59
<i>Chlorella sp.</i>	--	--	--	--	--	--	--	101.19	128.78	--	--	229.97
<i>Chlorella sp.</i>	--	--	--	--	--	--	--	61.60	--	--	--	61.60
<i>Chlorella sp.</i>	--	--	--	--	--	--	--	45.24	--	--	--	45.24
<i>Chlorella sp.</i>	--	--	--	--	--	--	--	--	507.14	--	--	507.14
<i>Chlorella sp.</i>	--	--	--	--	--	--	--	--	--	--	83.92	83.92
<i>Chlorella sp.</i>	--	--	--	--	--	--	--	--	--	--	--	3827.03

APPENDIX IV(c)

ZONE C DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm³/m³ x 0.001) JUNE 1978

	STATIONS				MEAN
	31	32	33	SUM	
<u>Cyclotella comta</u>	254.51	331.46	298.62	884.59	294.86
<u>Fragilaria crotonensis</u>	226.18			226.18	75.39
<u>Dinobryan sertularia</u>	148.84	186.05	206.49	541.38	180.46
<u>Cyclotella ocellata</u>	83.92	50.67	36.38	170.97	56.99
<u>Cyclotella bodanica</u>	65.48	87.31		152.79	50.93
<u>Cryptomonas borealis</u>	57.00	24.94	24.91	106.85	35.62
<u>Cyclotella stelligera</u>	38.57	16.36	14.02	68.95	22.98
<u>Dinobryan sp.</u>	34.00		28.91	62.91	20.97
<u>Dinobryan bavaricum</u>		16.10		16.10	5.37
<u>Stephanediscus astrea var minulata</u>		14.76		14.76	4.92
<u>Synedra ulna</u>			22.84	22.84	7.61
<u>Synedra radians</u>			13.76	13.76	4.59
					760.69

APPENDIX IV(d)

ZONE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($\text{cm}^3/\text{m}^3 \times 0.001$) SEPTEMBER 1978

	STATIONS												
	1	2	3	4	5	6	7	8	9	10	11	SUM	MEAN
<u>Surirella ovata</u>	1044.82	--	--	--	--	--	--	--	--	--	--	1044.82	94.98
<u>Synedra delicatissima</u>	237.77	83.92	90.91	55.95	34.97	90.91	97.91	62.94	83.92	83.92	97.91	1021.03	92.82
<u>Navicula gastrum</u>	77.81	--	--	--	--	25.94	--	--	--	25.94	--	129.69	11.79
<u>Melosira granulata</u>	58.02	32.23	36.53	32.23	--	--	--	116.04	36.53	--	--	311.58	28.33
<u>Anabaena sp2</u>	56.89	66.37	94.82	85.33	104.30	85.33	85.33	132.74	104.30	66.37	66.37	948.15	86.20
<u>Melosira granulata var augustissima</u>	52.89	102.34	83.94	66.69	112.69	45.99	44.84	80.49	86.24	51.74	64.39	792.24	72.02
<u>Aphanizomenon sp.</u>	51.69	--	--	68.92	25.84	--	--	51.69	--	--	34.46	232.60	21.15
<u>Tobellaria fenestrata</u>	43.83	--	--	--	--	--	--	--	--	--	--	43.83	3.98
<u>Anabaena sp.</u>	--	43.54	31.67	--	--	23.75	--	--	--	--	--	98.96	9.00
<u>Cryptomonas borealis</u>	--	42.75	32.06	71.25	64.13	60.57	49.88	67.69	49.88	64.13	53.44	555.78	50.53
<u>Fragilaria capucina</u>	--	28.50	--	28.50	--	--	--	--	--	--	--	57.00	5.18
<u>Fragilaria crotonensis</u>	--	28.10	45.50	--	--	--	--	--	41.49	--	--	115.09	10.46
<u>Cyclotella conta</u>	--	--	47.35	--	20.58	--	17.76	29.59	35.51	29.60	26.64	207.03	18.82
<u>Closterium sp.</u>	--	--	--	30.80	--	30.80	--	--	--	30.80	--	92.40	8.40
<u>Chroomonas acuta</u>	--	--	--	--	25.62	31.56	39.53	36.64	29.52	39.70	36.81	239.38	21.76
<u>Anabaena spiroides</u>	--	--	--	--	23.69	--	--	--	--	--	--	23.69	2.15
<u>Cymbella sp A</u>	--	--	--	--	--	--	111.14	--	--	--	--	111.14	10.10
<u>Anabaena sp3</u>	--	--	--	--	--	--	21.41	--	--	--	21.41	42.82	3.89
												551.56	

APPENDIX IV(e)

ONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($\text{cm}^3/\text{m}^3 \times 0.001$) SEPTEMBER 1978

	STATIONS																	SUM	MEAN
	12	13	14	15	16	17	21	22	23	24	25	26	27	28	29	30			
<u>Medra delicatissima</u>	69.93	41.96	41.96	76.93	83.92	62.94	62.94	45.58	84.01	42.07	54.28	--	55.95	31.50	40.88	79.47	874.32	54.65	
<u>Myrionomas borealis</u>	60.57	67.69	114.00	128.26	85.50	81.94	85.50	41.08	110.57	85.73	67.81	74.82	74.82	84.40	73.72	41.64	1278.05	79.88	
<u>Chaetoceros sp2</u>	56.89	66.37	47.41	47.41	37.93	56.89	28.44	28.52	28.47	33.27	35.61	28.44	--	--	--	--	495.65	30.98	
<u>Thalassiosira granulata</u>	38.68	--	--	58.02	--	30.08	--	--	--	--	--	--	--	--	--	--	126.78	7.92	
<u>Thalassiosira sp.</u>	34.46	34.45	25.84	34.46	34.46	17.23	--	--	34.50	38.87	30.18	25.84	43.07	34.49	28.74	21.57	438.16	27.39	
<u>Thalassiosira ocellata</u>	28.50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	28.50	1.78	
<u>Thalassiosira acuta</u>	27.65	52.93	33.08	34.27	30.54	31.22	33.08	20.16	24.55	19.22	26.21	30.20	34.44	25.23	27.74	23.24	473.76	29.61	
<u>Thalassiosira granulata var</u>																			
<u>Augustissima</u>	24.15	27.60	--	49.44	18.40	31.05	--	--	23.00	--	--	--	--	--	--	--	173.64	10.85	
<u>Thalassiosira comata</u>	--	53.27	29.60	73.99	47.35	50.31	73.99	23.74	32.60	14.84	71.88	82.86	73.99	55.28	47.90	48.07	779.67	48.73	
<u>Chaetoceros spiroides</u>	--	23.69	--	--	15.80	--	--	--	--	--	--	--	--	--	--	--	39.49	2.47	
<u>Medra radians</u>	--	--	23.00	--	--	--	--	--	--	--	--	--	--	--	--	--	23.00	1.44	
<u>Chaetoceros sp3</u>	--	--	21.41	--	--	--	--	--	--	--	--	--	--	--	--	--	21.41	1.34	
<u>Medinidium sp.</u>	--	--	--	--	--	--	665.48	--	--	--	--	--	--	--	--	--	665.48	41.59	
<u>Medinidium sp.</u>	--	--	--	--	--	--	402.71	--	--	--	--	--	--	--	--	--	402.71	25.17	
<u>Medinidium sp.</u>	--	--	--	--	--	--	30.80	15.44	--	--	--	--	--	--	--	--	46.24	2.89	
<u>Gillardia crotonensis</u>	--	--	--	--	--	--	--	17.45	--	23.48	--	37.47	--	--	16.75	42.83	137.98	8.62	
<u>Myrionomas sertularia</u>	--	--	--	--	--	--	--	17.32	--	14.66	--	--	82.39	20.38	--	--	134.75	8.42	
<u>Myrionomas sp.</u>	--	--	--	--	--	--	--	--	22.02	--	--	--	--	--	--	--	22.02	1.38	
<u>Myrionomas sp.</u>	--	--	--	--	--	--	--	--	--	--	23.47	--	--	--	--	--	23.47	1.47	
<u>Myrionomas sp.</u>	--	--	--	--	--	--	--	--	--	--	20.82	--	--	--	--	--	20.82	1.30	
<u>Myrionomas sp.</u>	--	--	--	--	--	--	--	--	--	--	--	24.50	--	--	--	13.58	38.08	2.38	
<u>Myrionomas sp.</u>	--	--	--	--	--	--	--	--	--	--	--	20.36	38.45	39.99	26.79	18.12	143.71	8.98	
<u>Myrionomas sp.</u>	--	--	--	--	--	--	--	--	--	--	--	--	33.23	--	--	--	53.23	3.33	
<u>Myrionomas sp.</u>	--	--	--	--	--	--	--	--	--	--	--	--	--	25.44	--	--	25.44	1.59	
<u>Myrionomas sp.</u>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	121.41	--	121.41	7.59	
																	411.75		

APPENDIX IV(f)

ZONE C DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($\text{cm}^3/\text{m}^3 \times 0.001$) SEPTEMBER 1978

	STATIONS				MEAN
	31	32	33	SUM	
<u>Cryptomonas borealis</u>	52.92	39.29	82.90	175.11	58.37
<u>Cyclotella comta</u>	48.91	72.53	164.40	285.84	95.28
<u>Arthrodesmus sp.</u>	35.68	--	--	35.68	11.89
<u>Rhopalodia gibba</u>	23.87	--	--	23.87	7.96
<u>Chlamydomonas sp.</u>	13.02	9.99	15.45	38.47	9.49
<u>Chroomonas acuta</u>	12.88	13.51	24.71	51.10	17.03
<u>Synedra delicatissima</u>	11.67	10.52	42.00	64.19	21.40
<u>Aphanizomenon sp.</u>	11.50	25.91	12.93	50.34	16.78
<u>Fragilaria crotonensis</u>	--	30.86	--	30.86	10.29
<u>Aphanothece sp.</u>	--	10.21	--	10.21	3.40
<u>Dinobryan sertularia</u>	--	--	15.96	15.96	5.32
<u>Cyclotella glomerata</u>	--	--	8.87	8.87	2.96
				260.17	

APPENDIX IV(h)

ONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($\text{cm}^3/\text{m}^3 \times 0.001$) NOVEMBER 1978

	STATIONS						
	*12	13	*14	*15	16	*17 - 20	SUM
<u>bellaria fenestrata</u>		89.48			186.87		276.35
<u>agilaria crotonensis</u>		74.34			134.62		208.96
<u>osterium sp</u>		69.36			23.12		92.48
<u>abaena sp2</u>		64.06			113.88		177.94
<u>ryptomonas borealis</u>		58.84			34.77		93.61
<u>nedra delicatissima</u>		36.75			31.50		68.25
<u>losira granulata</u>		22.58			--		22.58
<u>losira granulata var augustissima</u>		17.26			--		17.26
<u>terionella formosa</u>		--			18.68		18.68
<u>nobryan sertularia</u>		--			13.97		13.97
							<u>6.99</u>
							495.06

- - not sampled

APPENDIX IV(1)

TABLE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($\text{cm}^3/\text{m}^3 \times 0.001$) APRIL 1979

	STATIONS														
	1	2	3	SUM	MEAN	4	5	6	7	8	9	*10	11	SUM	MEAN
<u>Scenedesmus borealis</u>	1923.83	555.77	1482.06	3961.65	1320.55	976.17	783.78	573.59	760.95	997.88	1140.05	598.53	5830.95	832.99	
<u>Scenedesmus formosa</u>	702.12	532.02	546.50	1780.64	593.55	462.35	316.68	254.25	180.83	174.01	633.36	218.66	2240.14	320.02	
<u>Scenedesmus</u>	233.29	98.02	133.31	464.62	154.87	94.10	57.83	42.15	76.49	101.97	72.54	42.48	487.56	69.65	
<u>Scenedesmus</u>	228.76	--	49.46	278.22	92.74	46.37	27.82	--	42.53	25.51	55.65	20.09	217.97	31.14	
<u>Scenedesmus sertularia</u>	148.84	--	--	148.84	49.61	--	--	--	--	--	--	--	--	--	
<u>Gyrodinium crotonensis</u>	112.42	91.01	69.59	273.02	91.01	--	152.57	266.33	--	144.54	133.84	--	697.28	99.61	
<u>Gyrodinium sp.</u>	111.29	--	49.46	111.29	37.10	--	27.82	--	--	15.46	--	30.91	74.19	4.42	
<u>Microcystis gastrum</u>	103.75	--	--	103.75	34.58	--	--	--	--	--	--	--	--	--	
<u>Microcystis conta</u>	--	189.41	--	355.14	118.38	--	--	--	--	--	--	--	--	--	
<u>Microcystis</u>	--	108.80	69.59	108.80	36.27	--	--	72.54	54.54	--	--	--	126.99	18.14	
<u>Microcystis gibba</u>	--	95.22	--	95.22	31.74	--	--	--	--	--	--	--	--	--	
<u>Microcystis ocellata</u>	--	71.25	--	71.22	23.75	30.08	--	29.29	51.88	67.33	79.17	54.89	312.64	44.66	
<u>Microcystis delicatissima</u>	--	--	111.89	111.89	37.30	55.95	--	27.97	--	--	--	27.97	111.89	15.98	
<u>Microcystis stelligera</u>	--	--	37.40	37.40	12.47	--	--	--	--	--	--	--	--	--	
<u>Gyrodinium capucina</u>	--	--	--	--	--	38.00	19.00	--	--	--	--	--	57.00	8.14	
<u>Microcystis sp.</u>	--	--	--	--	--	22.02	66.05	--	--	30.28	44.03	--	162.38	23.20	
<u>Microcystis fenestrata</u>	--	--	--	--	--	--	--	49.09	--	--	--	--	49.09	7.01	
<u>Microcystis niagara</u>	--	--	--	--	--	--	--	--	106.47	--	--	--	106.47	15.21	
<u>Microcystis prostrata</u>	--	--	--	--	--	--	--	--	89.35	--	--	--	89.35	12.76	
<u>Microcystis granulata</u>	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
<u>Microcystis augustissima</u>	--	--	--	--	--	--	--	--	--	--	36.80	--	36.80	5.26	
<u>Microcystis nodinum sp.</u>	--	--	--	--	--	--	--	--	--	--	--	665.48	665.48	95.07	
				2633.92										1603.26	

Station 10 was not sampled in April 1979

APPENDIX IV(J)

ZONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($\text{cm}^3/\text{m}^3 \times 0.001$) APRIL 1979

	STATION
	*16
<u>Cryptomonas borealis</u>	206.09
<u>Gymnodinium sp.</u>	165.93
<u>Asterionella formosa</u>	41.36
<u>Arthrodesmus sp.</u>	38.43
<u>Melosira granulata</u>	19.29
<u>Cyclotella ocellata</u>	17.11
<u>Closterium sp.</u>	15.36
<u>Chlamydomonas sp.</u>	11.73
	515.3

* Station 16 was the control site in April 1979

APPENDIX IV(1)

ZONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($\text{cm}^3/\text{m}^3 \times 0.001$) JUNE 1979

*16

<u>Ceratium sp.</u>	1610.85
<u>Stephanodiscus niagare</u>	931.50
<u>Fragilaria crotonensis</u>	765.78
<u>Anabaena spiroides</u>	710.83
<u>Tabellaria fenestrata</u>	254.59
<u>Cryptomonas borealis</u>	187.89
<u>Dinobryan sertularia</u>	114.27
<u>Stephanodiscus astrea var minulata</u>	60.67
	4636.38

* Station 16 was the control site in June 1979

APPENDIX IV(n)

ZONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($\text{cm}^3/\text{m}^3 \times 0.001$) AUGUST 1979

*16

<u>Stephanodiscus niagare</u>	372.63
<u>Anabaena sp2</u>	284.45
<u>Melosira granulata</u>	146.13
<u>Aphanothece sp.</u>	108.58
<u>Anabaena spiroides</u>	94.78
<u>Aphanizomenon sp.</u>	86.14
<u>Tabellaria fenestrata</u>	73.63
<u>Cryptomonas borealis</u>	45.13
	1211.47

* - Station 16 was the control site in August 1979

APPENDIX IV(o)

ZONE A DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME ($\text{cm}^3/\text{m}^3 \times 0.001$) OCTOBER 1979

	STATIONS										SUM	MEAN
	1	2	3	4	5	6	7	8	9	10	11	
<u>Aphanizomenon sp.</u>	86.14	--	--	--	--	--	--	86.14	--	--	--	172.28 15.66
<u>Stephanodiscus niagarae</u>	53.23	--	--	--	79.64	--	53.23	--	26.55	39.82	--	252.47 22.93
<u>Melosira granulata</u>	36.53	--	--	--	22.50	22.50	23.64	40.11	16.07	--	--	161.35 14.67
<u>Ankistrodesmus sp.</u>	29.03	24.88	32.35	24.05	30.40	30.40	38.15	24.88	26.06	23.74	43.96	297.50 27.05
<u>Oscillatoria sp.</u>	27.20	--	--	36.27	--	54.26	36.27	36.27	54.26	40.77	72.54	357.84 44.73
<u>Crocononas acuta</u>	27.14	31.39	32.74	32.40	23.10	28.55	31.39	--	19.20	30.20	33.76	289.87 26.35
<u>Cryptomonas borealis</u>	24.94	57.00	39.19	42.75	39.97	58.63	35.63	54.63	37.31	29.08	24.94	444.07 40.37
<u>Aphanothece sp.</u>	24.88	36.19	--	--	--	--	--	--	--	--	--	61.07 5.55
<u>Anabaena sp3</u>	--	107.07	107.07	--	--	--	--	--	--	--	--	214.14 19.47
<u>Anabaena sp.</u>	--	79.17	98.96	98.96	74.03	74.03	138.55	98.96	69.09	79.07	79.17	889.99 80.91
<u>Fragilaria crotonensis</u>	--	64.24	--	--	--	--	24.09	--	--	--	--	88.33 8.03
<u>Chlamydomonas sp.</u>	--	23.03	21.07	--	19.43	23.46	--	--	--	--	--	86.99 7.91
<u>Closterium sp.</u>	--	--	30.80	--	--	--	--	--	--	--	--	30.80 2.80
<u>Synedra radians</u>	--	--	20.70	--	--	--	--	--	--	--	--	20.70 1.88
<u>Anabaena spiroides</u>	--	--	--	157.96	59.08	59.08	--	--	--	--	--	276.12 25.10
<u>Microcystis sp.</u>	--	--	--	36.29	--	--	--	--	--	24.73	16.49	77.51 7.05
<u>Cyclotella comta</u>	--	--	--	23.68	--	--	--	23.68	--	--	--	47.36 4.31
<u>Tabellaria fenestrata</u>	--	--	--	--	--	--	--	28.05	--	--	--	28.05 2.55
<u>Diatoma vulgare</u>	--	--	--	--	--	--	--	--	20.59	--	--	20.59 1.87
<u>Synedra delicatissima</u>	--	--	--	--	--	--	--	--	--	27.96	55.95	83.91 7.63
<u>Gomphonema herculeanum</u>	--	--	--	--	--	--	--	--	--	--	69.52	6.32 373.16

APPENDIX IV(p)

ZONE B DOMINANT ALGAE - PHYTOPLANKTON BIOVOLUME (cm³/m³ x 0.001) OCTOBER 1979

	*16
<u>Oscillatoria sp.</u>	99.59
<u>Anabaena sp.</u>	84.00
<u>Microcystis sp.</u>	72.57
<u>Cryptomonas borealis</u>	67.63
<u>Stephanodiscus niagare</u>	46.53
<u>Ankistrodesmus sp.</u>	36.24
<u>Chroomonas acuta</u>	26.98
<u>Chlamydomonas sp.</u>	21.91
	455.45

* Station 16 was the control site in October 1979

APPENDIX V

PERIPHYTON ASH-FREE WEIGHT
AT SHALLOW WATER STATIONS
IN SHUSWAP LAKE
DURING 1979

APPENDIX V(a)

PERIPHYTON ASH-FREE WEIGHT ($\text{mg}/\text{m}^2/\text{day}$) AT SHALLOW WATER STATIONS IN SHUSHAP LAKE DURING 1979

STATIONS	END OF APPROXIMATE THREE-WEEK PERIODS									
	May 8	May 29	June 19	July 12	July 31	Aug. 21	Sept. 11	Oct. 2	Oct. 23	Mean
SA-S1	--	--	215.0	83.3	363.2	361.9	90.5	71.4	20.0	172.2
SA-S2	50.0	19.0	15.0	54.2	31.6	276.2	38.1	--	15.0	62.4
SA-S3	56.3	19.0	30.0	54.2	36.8	57.1	52.4	28.1	20.0	40.4
SA-S4	31.3	90.5	110.0	20.8	42.1	33.3	76.2	47.6	15.0	51.9